SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER ENVPREDRSCHFAC Technical Paper No. 9-74	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) A Role of the Tropical Upper Tropospheric Trough in Early Season Typhoon Development	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER UHMET 73-04
7. AUTHOR(s) James C. Sadler	8. CONTRACT OR GRANT NUMBER(s) N66314-73-C-1770
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Meteorology University of Hawaii Honolulu, Hawaii 96822	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS PE 62759N PN 52551 TA WF52-551-713 EPRF WU 054:2-1
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Systems Command Department of the Navy Washington, D.C. 20361	12. REPORT DATE May 1974
	13. NUMBER OF PAGES 54
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Environmental Prediction Research Facility Naval Postgraduate School Monterey, CA 93940	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; Distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Tropical cyclone forecasting
Satellite meteorology
Typhoon Freda, June 1971
Typhoon Gilda, June 1971
Typhoon Harriet, June 1971
Early season typhoon development
Tropical upper tropospheric trough

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AN (1) AD- 782 364
FG (2) 040200
CI (3) (U)
CA (5) HAWAII UNIV HONOLULU DEPT OF METEOROLOGY
TI (6) A Role of the Tropical Upper Tropospheric Trough in Early Season Typhoon Development.
TC (8) (U)
DN (9) Technical paper,
AU (10) Sadler,James C.
RD (11) May 1974
PG (12) 57
RS (14) UHMET-73-04
CT (15) N66314-73-C-1770
PJ (16) WF52-551-713
RN (18) ENVPREDRSCHF-Techpaper-9-74
RC (20) Unclassified report
DE (23) *TYPHOONS, *TROPOSPHERE, *WEATHER FORECASTING, *PACIFIC OCEAN, CIRCULATION, PATTERNS, WIND VELOCITY, METEOROLOGICAL SATELLITES, CLOUDS, KINEMATICS
DC (24) (U)
ID (25) Tropical upper tropospheric trough, Typhoon Freda, Typhoon Gilda, Typhoon Harriet, Spaceborne photography, North Pacific Ocean
IC (26) (U)
AB (27) During each of three occasions in June of 1971 that the Tropical Upper Tropospheric Trough (TUTT) extended into the western North Pacific along 15N, a typhoon developed in the low-level trough between 5N and 10N. Detailed analyses of the upper-tropospheric wind field during the early stages of the three typhoons -- Freda, Gilda, and Harriet -- are used to develop a synoptic model which describes the role of the TUTT in early season typhoon development. (Author)
AC (28) (U)
DL (33) 01
CC (35) 406855

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ENVPREDRSCHFAC
Technical Paper No. 9–74

UHMET 73–04

A ROLE OF THE TROPICAL UPPER TROPOSPHERIC TROUGH IN EARLY SEASON TYPHOON DEVELOPMENT

by

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JUNE 1974

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CONTENTS

ABSTRACT

During each of three occasions in June of 1971 that the Tropical Upper Tropospheric Trough (TUTT) extended into the western North Pacific along 15N, a typhoon developed in the low-level trough between 5N and 10N. Detailed analyses of the upper tropospheric wind field during the early stages of the three typhoons -- Freda, Gilda, and Harriet -- are used to develop a synoptic model which describes the role of the TUTT in early season typhoon development.

I. INTRODUCTION

The increasing quantity and quality of wind observations from jet aircraft platforms and excellent satellite data have focused attention in the past few years on the role of the upper troposphere in the tropical storm problems of development, movement, and variations in intensity.

There is increasing evidence that an important factor in storm intensity changes is the facility with which the systems are furnished a multidirectional outflow channel for removing the excess heat by the large scale circulation patterns of the upper troposphere. Figure 1 is a simple schematic illustrating the interaction of storm outflows with common large scale circulation patterns.

In Figure 1(a) the storm is located in a region of upper tropospheric northeasterlies. An anticyclonic outflow is impeded over much of the area and is directly opposed in the northern sector. Figure 1(a) is very similar to the mean upper flow during summer in the western North Pacific, being east-northeast with increasing speeds westward -- or climatologically an ideal flow pattern for only the southern sector of the outflow. A facilitated outflow in the northern sector requires a channel to a westerly current. In late season (October and November) this channel is often furnished by the deep troughs in the mid-latitude westerlies similar to the sketch in Figure 1(b). Ramage (1973) presented case studies to show the dominant influence of such troughs on the intensity of typhoons in the South China Sea during October. Erickson and Winston (1972) studied the role of the outflow from autumn tropical cyclones in increasing the circulation of the mid-latitude westerlies. The east side of deep troughs in the westerlies was a principal outflow channel for each cyclone. The satellite observed cloud bands extending northeastward from intense tropical cyclones attest to the importance of an

outflow channel to the mid-latitude westerlies in maintaining the intensity of these autumn storms in the Bay of Bengal. See for example, page 129 of the 1972 Annual Typhoon Report (U.S. FWC/JTWC, 1972). An outflow to the westerlies has long been recognized as a requirement for tropical storm development in the Australian region (Wilkie, 1964). Colon and Nightingale (1963) found that the majority of Atlantic hurricanes intensify under conditions of outflow to a westerly channel.

During summer, troughs in the mid-latitude westerlies seldom extend into the tropical western North Pacific; therefore, we must look to some other circulation feature for an outflow channel to westerlies. This circulation feature is the Tropical Upper Tropospheric Trough (TUTT) as illustrated in Figure 1(c). The influence of the TUTT in the rare development of storms in the South China Sea during summer was noted by Sadler et al. (1968). Sadler and Harris (1971) noted the complex interaction between multiple tropical storms and the TUTT during the summer of 1967. The westerly outflow channel switched back and forth between Typhoon Ellen and Tropical Storm Georgia and their intensities (as deduced from the satellite observations) increased with access to a westerly outflow channel and decreased when the channel was not available.

The development period is the time of extreme intensity changes and this study concerns the role of the TUTT in the development of Typhoons Freda, Gilda, and Harriet during June of 1971. These storms were chosen because of the relatively simple synoptic patterns, the repetitive similarity of the synoptic patterns during each development period, the relative abundance of aircraft wind observations, and good satellite observations from both daytime visual and nighttime infrared sensors.

2. DATA SOURCES AND ANALYSES

1. KINEMATIC ANALYSES

1200 GMT was chosen for the once-each-day analyses because published ship data are available from the Northern Hemisphere Data Tabulation for this time only.

The 250-mb level was selected for the upper tropospheric analysis because aircraft wind observations are more numerous near this level. The aircraft data source was the operational "plotrep" charts of the Fleet Weather Central at Pearl Harbor. To minimize data voids, the 250-mb chart was augmented by observations from the 200-mb and 300-mb charts and by off-time data from the 0600 GMT and 1800 GMT charts. The off-time data were plotted in different colors to avoid some of the confusion in analysis; however, the confusion which may arise from meshing off-level and off-time data is far outweighed by the advantage of increased data coverage. The high speed currents are of major concern and these are fairly conservative over the analysis time scale.

2. SATELLITE DATA

The computer rectified mosaic of the tropical strips from the NOAA I satellite were the source of cloud data. Infrared data on the same format were available for most of the period. The times of coverage in the western Pacific were near 0600 GMT for the visible and 1800 GMT for the infrared.

In addition to general utility in the analysis program, the satellite data were particularly useful for three specific purposes.

a. To monitor the amount and organization of cloud systems in the low level trough.

b. To position the center of cyclonic cells in the TUTT. The utilization for this purpose is quite variable. On some days the upper circulation is well outlined by cirrus bands

and/or organized cumulus clouds in a vortical pattern. On other days the clouds outline only one sector of the circulation, usually the south through east, and on some days there are no clouds or obvious organization of clouds near the circulation center.

c. To detect and position the narrow ribbons of high wind speed. The high wind speeds on either side of the TUTT and around the cyclonic cells will at times be associated with narrow bands of "independent" cirrus of sufficient thickness to show clearly on the satellite picture. Independent observations from aircraft and rawins located in or near the edge of the cirrus cloud band generally verify wind speeds of greater than 50 kt at 35,000 ft. There is a reasonable agreement between the wind direction at 35,000 ft and the alignment of the cirrus bands; however, it should be kept in mind that the agreement may be better with the flow at higher levels for, in general, the tropical wind speeds increase with height to the maximum near 45,000 ft (Kakugawa and Adams, 1966).

Caution: Although independent bands are indicative of high wind speeds, the corollary is not true. A majority of the time, the high speed currents do not have an associated visible cirrus band as observed by the current ESSA and NOAA medium resolution visual and IR channels.

To aid in comparing the satellite observed cloud system and the observed wind field, the strong wind currents from the streamline analysis are shown on the satellite pictures by lines of short arrows and the bands of independent cirrus from the satellite photographs are shown on the streamline analyses by serrated lines. Keep in mind that the observations are not truly synoptic but cover a period of plus or minus some 6 hours and no data positions have been adjusted.

3. GENERAL SYNOPTIC FEATURES -- JUNE 1971

Three storms in June are almost twice the normal for the western Pacific; yet, there was no obvious abnormality in the low-level atmospheric features. The surface trough was near its normal June position between 5N and 10N. Pressures in the trough were 1008 mb to 1010 mb. The low-level westerlies near 5N seldom extended eastward of 140E.

The abnormality, if any, appears to be in the upper troposphere. The uncertainty is due to the fact that only within the past few years of good aircraft wind observations has it been possible to depict in sufficient detail the upper tropospheric flow, so it may be premature to speak of anomalies. In any event, the TUTT was intense and a dominant feature during June of 1971. It was very persistent in the eastern Pacific and westward to near 160E. There were periodic westward extensions of the trough into the extreme western Pacific. Each extension was initiatied by the westward track between 15N and 20N of an upper-level cyclonic cell from the region near Wake Island.

Figure 2 is the mean 250-mb circulation for the period of 13-24 June 1971. The mean was produced from the daily analyses by extracting the wind direction and speed at grid points spaced 2° latitude by 2° longitude. The twelve days of grid point data were summed and mean resultant winds calculated. The TUTT is much more pronounced than in the long term mean (Sadler, 1972). However, as mentioned above, this may be a typical June pattern for some individual years.

4. DESCRIPTIVE MODEL

During each of the three occasions in June of 1971 that the TUTT extended into the western Pacific, a tropical storm developed in the low-level trough between 5N and 10N near the islands of Koror (7.3N, 134.5E) and Yap (9.5N, 138.1E). The schematic of Figure 3 illustrates the change in the upper flow pattern during these cycles. In Figure 3(a) the TUTT terminates near 160E and the upper tropospheric flow is northeasterly over the tropical western Pacific. Figure 3(b), a few days subsequent to Figure 3(a), depicts the flow pattern as the TUTT extends westward to 130E. A ribbon of westerly winds lies between the TUTT and the accompanying subequatorial ridge which lies over the low-level trough. The effect of these changes aloft is hypothesized as two-fold. First, the divergent stream indicated by the arrows in Figure 3(b) (also speed divergent due to stronger westerlies just south of cyclonic cell) increases the evacuation aloft to initiate a low in the surface trough (indicated by a D in Figure 3(b). Secondly, a channel to the westerlies is established for increased outflow of the heat released by increased convection in the developing depression.

5. CASE STUDIES

As mentioned earlier, Typhoons Freda, Gilda, and Harriet all formed in a common area during quite similar large-scale circulation features. Gilda was selected for the prime illustration because the TUTT cell of interest was intense and well depicted on most days by the satellite observed cloudiness in both the visual and infrared data.

1. TYPHOON GILDA

Figure 4 shows the time and space relationship in the tracks of the TUTT cyclone 1 (UC-1 for reference convenience) and Typhoon Gilda. The Gilda track was taken from the 1972 Annual Typhoon Report.

UC-1 had a relatively slow westward movement of 6 kt from 15N, 161E on 16 June to 15N, 148E on 21 June. It then accelerated, changed to an increasingly northward track, and decayed on the 25th near 26N, 134E.

The Gilda low formed near 8N, 143E on 20 June and moved westward. It passed south of Yap (9.5N, 138.1E) near 0600 GMT on the 22nd and the first Joint Typhoon Warning Center (JTWC) bulletin, based on a satellite fix at 0634 GMT, 22 June, placed the depression near 8N, 138E. The storm attained typhoon intensity on the 24th near 11N, 127E.

a. <u>16 June 1971</u>

The TUTT was quite intense in the central Pacific between 160E and 180 as indicated by the observed wind speeds of 70 kt in both the northeast and southwest currents (Figure 5). Independent cirrus (Figures 6 and 7) was associated with the strong wind speeds in both currents. UC-1 was not uniquely determined by either the wind observations or the cloud pattern but a combination of the two placed the center near 15N, 161E. Upper tropospheric northeasterlies of moderate strength covered

the western North Pacific south of 15N, west of 155E. A residual section of the TUTT associated with the previous Typhoon Freda remained in the extreme western Pacific between 15N and 20N.

b. 17 June 1971

The UC-1 moved very slowly westward and, as on the 16th, it required a combination of aircraft wind observations (Figure 8) and the satellite cloudiness (Figures 9 and 10) to place the cell near 15N and 160E. The residual portion of the TUTT in the extreme western Pacific decayed further and northeasterly flow covered the western Pacific south of the subtropical ridge and west of 155E. The circulation pattern was quite similar to the initial day of the model of Figure 3(a).

c. 18 June 1971

The strong circulation of UC-1 (Figure 11) was outlined by the cirrus bands in the infrared (Figure 12) and the visual (Figure 13) satellite data and the satellite-determined position near 15N, 158E fitted well with the wind observations. A weak extension of the TUTT westward from UC-1 along 16N to 135E was indicated by the PIREPS (Figure 11). There was a general diminution of cloudiness between 5N and 10N, from 130E to 165E from the 16th of June near 1800 GMT (Figure 9) through the 17th (Figures 10 and 12). By June 18th (Figure 13) there were no significant convective cloud systems in this zone. This observation is important to establish the fact that the subsequent development of the Gilda low on 20 June was not from a system moving westward in the low-level trough.

d. <u>19 June 1971</u>

UC-1 continued slowly westward to near 15N, 155E (Figure 14). The circulation was indicated by the cloud pattern of the infrared depiction (Figure 15) but the character of the cloudiness changed to more convective near the center. Twelve hours later on the visual channel picture (Figure 16) the cirrus bands were indistinct and deep convective clouds were located in the east sector of the circulation. The narrow extension of the TUTT westward from UC-1 reached 130E (Figure 14). The strong winds on the north side of UC-1 were sampled by aircraft but no observations were available for the southern sector.

The low-level trough (Figure 17) extended east-southeast from the Philippines through the region of Koror (7.3N, 134.5E) and Yap (9.5N, 138.1E) and, though the westerlies extended to beyond 140E, there was no obvious closed wind circulation in the trough. The UC-1, noted on the surface map at 15N, 155E, overlies low-level easterly flow and there is no reflection of the upper cell in the low-level wind field. The satellite data, as on 18 June, showed no organized cloudiness in the low-level trough between 130E and 155E (Figures 15 and 16) and, in fact, there was remarkably little cloudiness in this region.

e. <u>20 June 1971</u>

UC-1 continued slowly westward to near 15N, 154E (Figure 18). The character of the cloudiness near UC-1 changed and once again the center is ringed by bands of cirrus (Figures 19 and 20). Some strong winds were observed in the north quadrant of UC-1 but again there were no observations in the south quadrant (Figure 18); however, the sharp edge of the increased cirrus (Figure 20) indicated the probability of strong winds south of the center near 10N. The narrow band

of westerlies south of the TUTT between 8N and 12N and east of 130E were sampled by three aircraft and the wind at Yap turned to southwesterly (Figure 18).

The surface observations at Yap and Woleai (7.4N, 143.9E) and their changes from the previous day indicated that a closed wind circulation had formed between the two stations and backward and forward extrapolation placed the center near 8N, 143E (Figure 21). As on 19 June, the UC-1 overlies a broad and weak easterly surface flow.

Satellite observations showed a dramatic increase from the previous day (compare Figures 16 and 20) of cloudiness in the latitude belt of 5N to 10N and heavy convective cloudiness surrounded the surface circulation on the west, south and east sides. The circulation center was in a relative cloud minimum area -- a common feature in the early stages of cyclone development in the low-level trough (Sadler *et al*., 1968; Shiroma and Sadler, 1965).

f. 21 June 1971

The UC-1 continued westward and the speed increased to some 12 kt (Figure 22). Its circulation was well outlined in both the infrared and visual satellite data (Figures 23 and 24) by the vortical pattern of the scattered cloudiness around the center. A pronounced band of independent cirrus, particularly striking in the visual data, extended eastward from near 13N, 136E and wrapped around the south and east side of the UC-1. Winds of 50 kt were observed north and south of UC-1 (Figure 22) but the strong winds in the narrow cirrus band were not sampled.

The Gilda surface low was near 8N, 140E (Figure 25). The UC-1 remained over a broad light easterly flow. The convective cloudiness remained quite extensive around the surface low (Figures 23 and 24) but there was yet no organized mass near or over the center.

g. 22 June 1971

UC-1 began curving toward the northwest and the speed increased to approximately 15 kt (Figure 26). The center was well depicted by the vortical cloud pattern on the infrared data (Figure 27) but not on the visual (Figure 28). However, the visual data showed two distinct cirrus bands of different orientation. One was a very thin cirrus band oriented from 15N, 130E southeastward to 12N, 137E and the other a more dense cirrus band emanating from the deepening depression and extending northeastward around the east sector of UC-1. These orientations meshed quite well with the upper circulation (Figure 26) and indicated that the aircraft observation at 12N, 141E should be from 200 rather than 100 degrees. The ignored aircraft observation at 16N, 141E cannot be so easily reconciled. The combination of the cirrus band, the southwesterly 35 kt wind at 30,000 ft, and the southerly wind at 25 kt at Guam at 250 mb indicated a strong upper-level outflow from the region of the surface depression whose position is marked by the storm symbol on Figure 26.

Note that the TUTT had become segmented and UC-1 was separated from the portion in the central Pacific by a large region of weak anticyclonic winds. UC-2 was in the central Pacific portion of the TUTT near 16N, 172E.

The Gilda surface depression was near 9N, 136E (Figure 29). Gilda passed just south of Yap near 0600 GMT, 22 June. The observed winds at Yap at 0000 GMT, 22 June, were easterly at 15 kt from the surface to 10,000 ft, while the 1200 GMT winds at Yap were 30 kt or greater from the southeast in the lower 10,000 ft with a maximum of 40 kt observed at 7000 ft. This moderate increase of winds as the system moved away from Yap indicated that the system was intensifying and the satellite photograph near 0600 GMT (Figure 28) showed some increase in cloud organization from the previous day.

h. <u>23 June 1971</u>

UC-1 continued to curve toward the northwest at a speed of some 16 kt to a position near 20N, 137E (Figure 30). The circulation was outlined by the vortical pattern of cloudiness (Figures 31 and 32) and a cirrus band continued to be visible extending northeastward from a position north of storm Gilda around the east side of UC-1. This orientation agreed quite well with the upper circulation (Figure 30). A rather broad upper-level outflow channel to the north and northeast was available to Gilda and in fact the most simple analysis of the observed winds, as protrayed in Figure 30, indicated that Gilda was under an upper-level southwesterly flow. However, a normal interpretation of the satellite photograph (Figure 32) would indicate a northerly component of the upper winds on the east side of Gilda between 138E to 140 E and 5N to 10N. Figure 30(a) is an alternate analysis which better accommodates the satellite observations and also permits the cyclonic circulation of the storm to extend into the upper troposphere. A time-latitude cross section of the Koror (7.3N, 134.5E) winds (not shown) indicated that both the 0600 and 1200 GMT observations were within the storm circulation from the surface to 40,000 ft.

Gilda was positioned near 9N, 133E (Figure 33) and the satellite observation near 0600 GMT (Figure 32) showed a good organization of the Gilda cloud system. There were still large breaks in the clouds near the circulation center, or, in other words, no central dense overcast. The first reconnaissance penetration at 0030 GMT, 24 June reported winds of 30 kt.

The segmentation of the TUTT which began on 22 June (Figure 26) was complete on the 23rd (Figure 30). A wide belt of moderate northeasterly flow separated the UC-1 from UC-2 which was located near 16N, 168E. The upper circulation pattern on the 23rd was quite similar to that of the 16th (Figure 5), particularly the circulations around UC-1 on the 16th and UC-2 on the 23rd.

i. <u>24 June 1971</u>

UC-1 continued on a curving track toward the northwest and by 24 June had begun to pass through the subtropical ridge (Figure 34). There remained an upper-level outflow channel from Gilda toward the northeast around the south and east sides of UC-1. It was particularly noticeable in the bridging cirrus band of the infrared photograph (Figure 35). This outflow channel was open to the mid-latitude westerlies.

A reconnaissance aircraft positioned Gilda at 1245 GMT at 11.0N, 127.4E and observed maximum winds of 55 kt at 1500 ft. The satellite observation some 6 hours earlier (Figure 36) indicated an increased cloud organization from the previous day and a small core cloud had formed over the center.

2. TYPHOON HARRIET

The tracks of UC-2 and Harriet during the early development stage are shown in Figure 4. The early stages of Harriet could be traced, by satellite, back to the region of 9N, 142E on 28 June 1971. The weak depression passed over Yap (9.5N, 138.1E) near 1200 GMT on the 29th, and reached tropical storm intensity on the 1st of July.

Only a minimum selection of upper air analyses and satellite photographs are presented for the early stages to illustrate the similarities and/or differences in the features of the upper circulation during Gilda and Harriet for general support of the model shown in Figure 3.

Refer to the upper circulation on 24 June (Figure 34) and compare it with that of the 28th (Figure 37) and 29th (Figure 38) to note the changes in the upper flow over the tropical western Pacific as UC-2 moved westward from near 15N, 162E to near 15N, 143E at an average speed of some 9 kt.

A belt of moderate westerlies between the re-established subequatorial ridge and the TUTT replaced the moderate northeasterly flow of the 24th. This sequence was identical to the one preceding the development of Gilda as discussed previously. The major difference was that the observed circulation around UC-2 was not as large or as intense as that of UC-1. The observed winds in both the easterly and westerly currents of UC-2 were 30 to 35 kt versus the 50 kt or greater in UC-1.

Probably as a result of the lower wind speeds, the UC-2 circulation was seldom obvious in the satellite observed cloudiness (Figures 39, 40, and 41). Essentially, no dependent cirrus bands were generated and no towering cumulus were developed for vortical organization near the cell center. Only on the 30th (Figure 41) was the cell outlined by organized clouds and then only around the south semicircle, principally by the bridging cirrus band in the strong outflow from Harriet around the south and east side of UC-2.

There was an increase in organized cloudiness associated with the Harriet depression from the 28th as observed by the satellite (Figures 39, 40, and 41). On 1 July (Figure 42) there was a small cirrus canopy over the circulation center. The first aircraft penetration at 0447 GMT on 1 July reported winds of 25 kt and, some 24 hours later, the next reconnaissance penetration at 0400 GMT on 2 July estimated 70 kt surface winds.

3. TYPHOON FREDA

The Freda depression formed west of Koror (7.3N, 134.5E) on 11 June with an initial northeastward drift before turning toward the northwest on the 12th, and reached tropical storm intensity late on the 13th.

The track of Freda during the development period and the position of UC-3 on 11 June are shown in Figure 4. The relative positions of the pre-Freda depression and UC-3 were identical to those of Gilda and UC-1 and of Harriet and UC-2.

The upper-level analysis on the 11th (Figure 43) indicated that the circulation of UC-3 was not a large vortical cell similar to UC-1 but small within a narrow, but intense, shear zone similar to UC-2. However, a narrow high speed westerly current of 50 kt or greater was observed south of UC-3 by three aircraft and a thick independent cirrus band was observed by satellite (Figure 44) in the high speed current. The increase of cirrus banding on subsequent days (Figures 45, 46, and 47) indicated that the westerly current remained very strong between 10N and 15N eastward to at least 165E.

There was an increase in the cloud organization associated with the Freda depression beginning on 11 June in the region of 5N-10N, 130E-135E. The reconnaissance penetrations at 1500 ft on the 14th at 0734 GMT and 1915 GMT estimated surface winds of 40 kt and 60 kt, respectively.

6. SUMMARY

These case studies strongly suggest that an upper tropospheric outflow channel to a large scale westerly flow, in addition to the normally available channel to the tropical easterlies, is important in the development of tropical cyclones. In these studies this channel to the westerlies was supplied by an extension of the TUTT into the western Pacific. The TUTT is a dominant feature of the upper troposphere throughout the summer in the Pacific and is likely to be of key importance to the variations of typhoon intensities throughout their life cycles. Therefore, a detailed analysis of the upper troposphere is essential to the important, but, heretofore, elusive forecast of intensity changes.

The current centralized objective analyses are not adequate for typhoon forecasting. The upper circulations during this study were relatively simple, intense, and had excellent time continuity, yet the history of the most intense cell (UC-1) could not be determined from the operational objective analyses. It is apparent that satellite and other available data were not incorporated into these analyses and that such data must be incorporated if these products are to serve a useful function in meeting the needs of a tropical forecast center.

ACKNOWLEDGMENTS

Appreciation is expressed to Mr. Louis Oda for plotting and drafting the figures and to Mrs. S. Arita for typing the manuscript.

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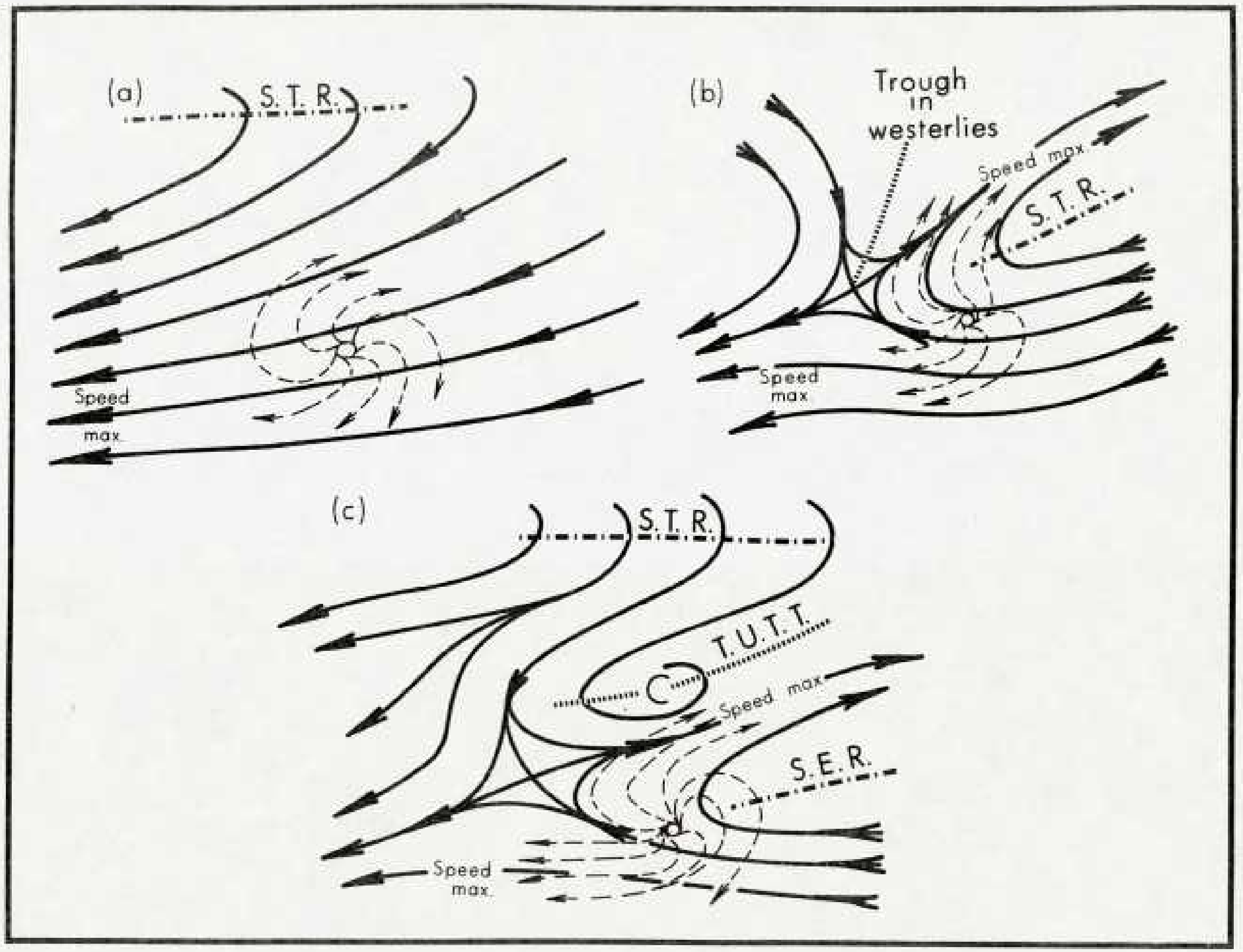

Figure 1. Schematic of storm outflow interaction (dashed lines) with the larger scale circulation (solid lines). STR is the Subtropical Ridge; SER, the Subequatorial Ridge; and TUTT, the Tropical Upper Tropospheric Trough.

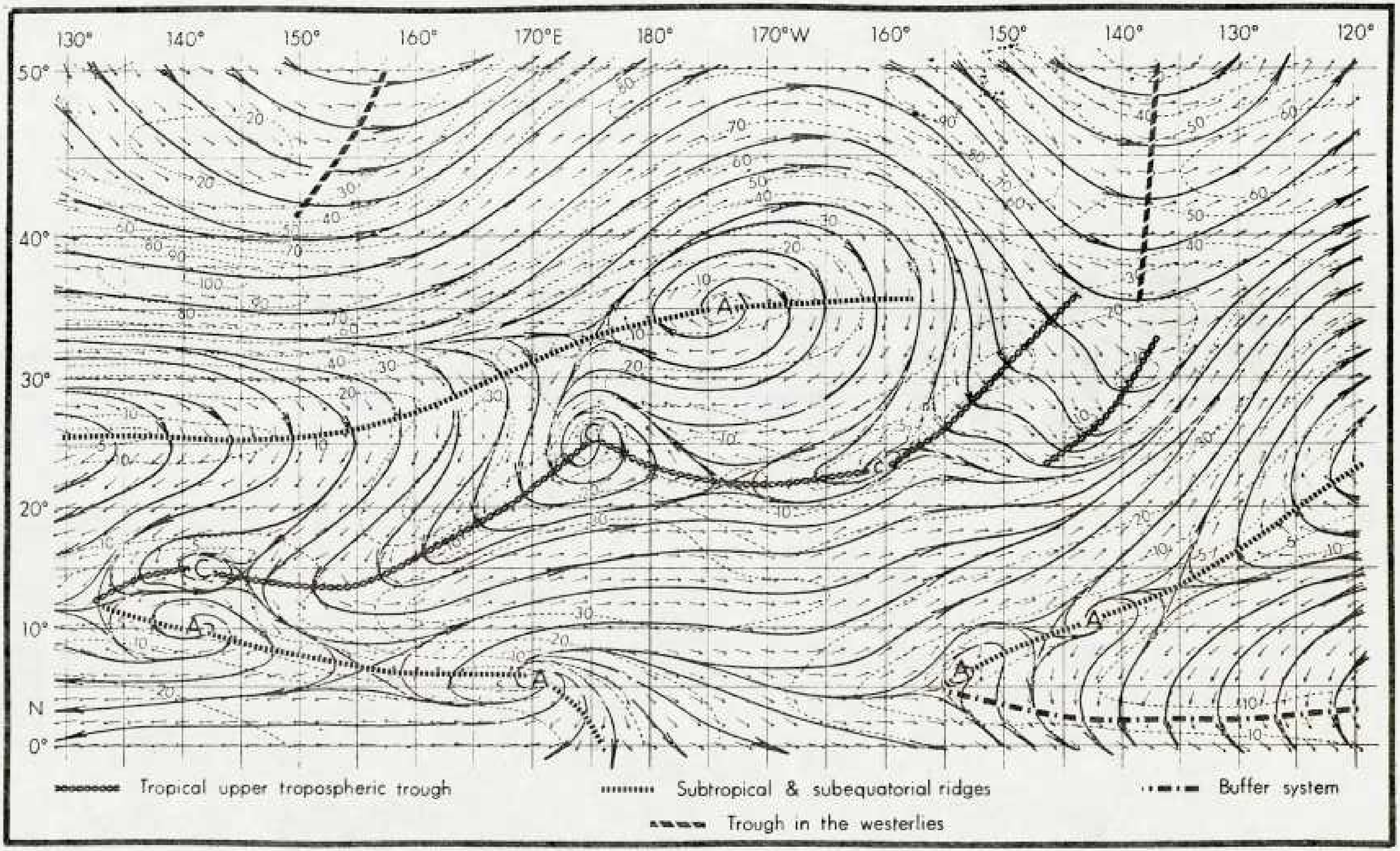

Figure 2. The mean 250 mb circulation during the period of 13-24 June 1971. Wind speed in kt shown by dashed lines.

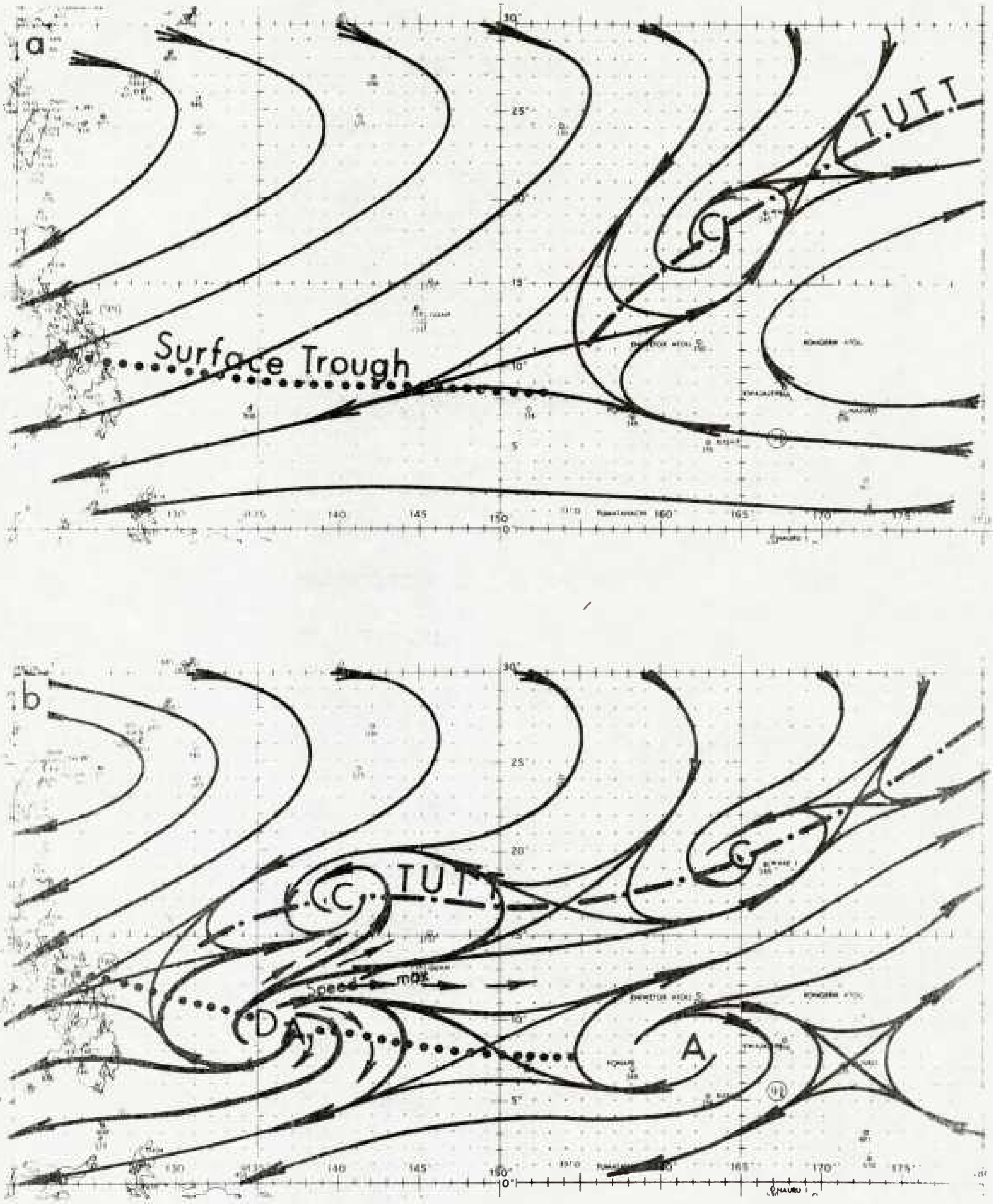

Figure 3. A model of the upper tropospheric circulation changes as a mechanism for increased outflow for developing storms in the western North Pacific. Section a shows the TUTT terminated near 160E and Section b shows the TUTT extending westward to 130E.

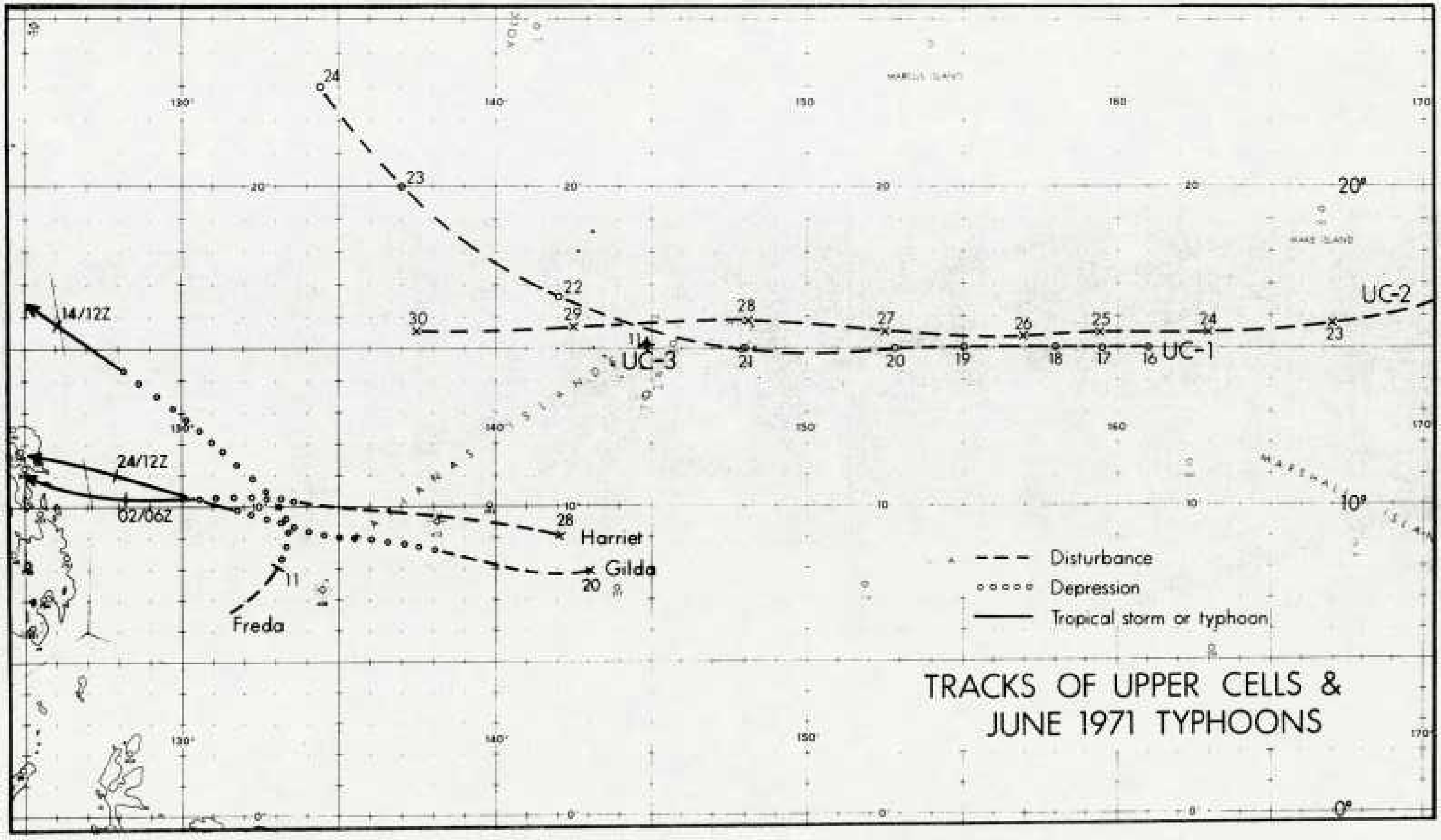

Figure 4. The tracks of Gilda, Harriet, and Freda and of the upper tropospheric cyclonic cells UC-1, UC-2, and UC-3.

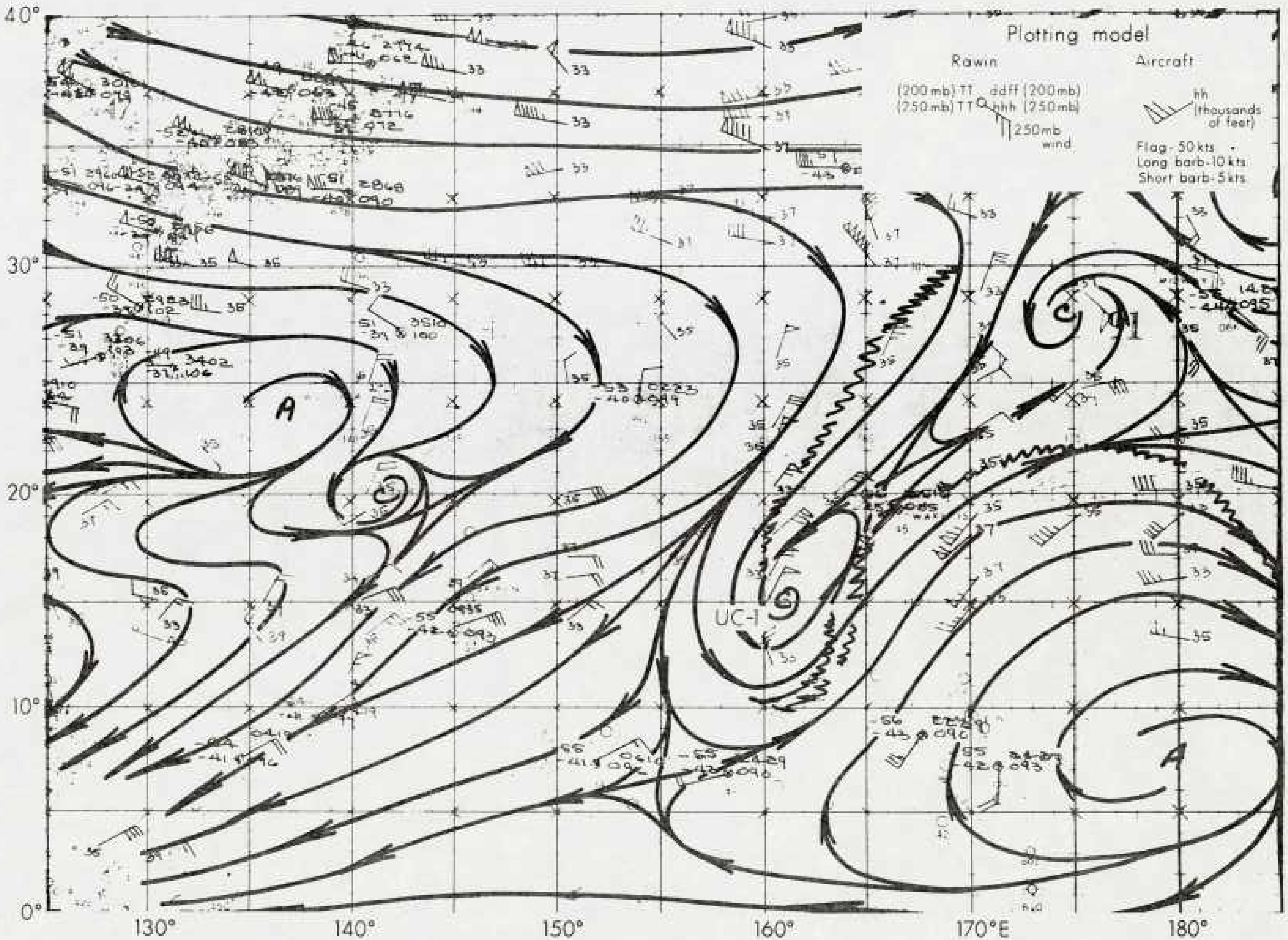

Figure 5. 250 mb analysis - 1200 GMT 16 June 1971. Plotting model in upper right insert.

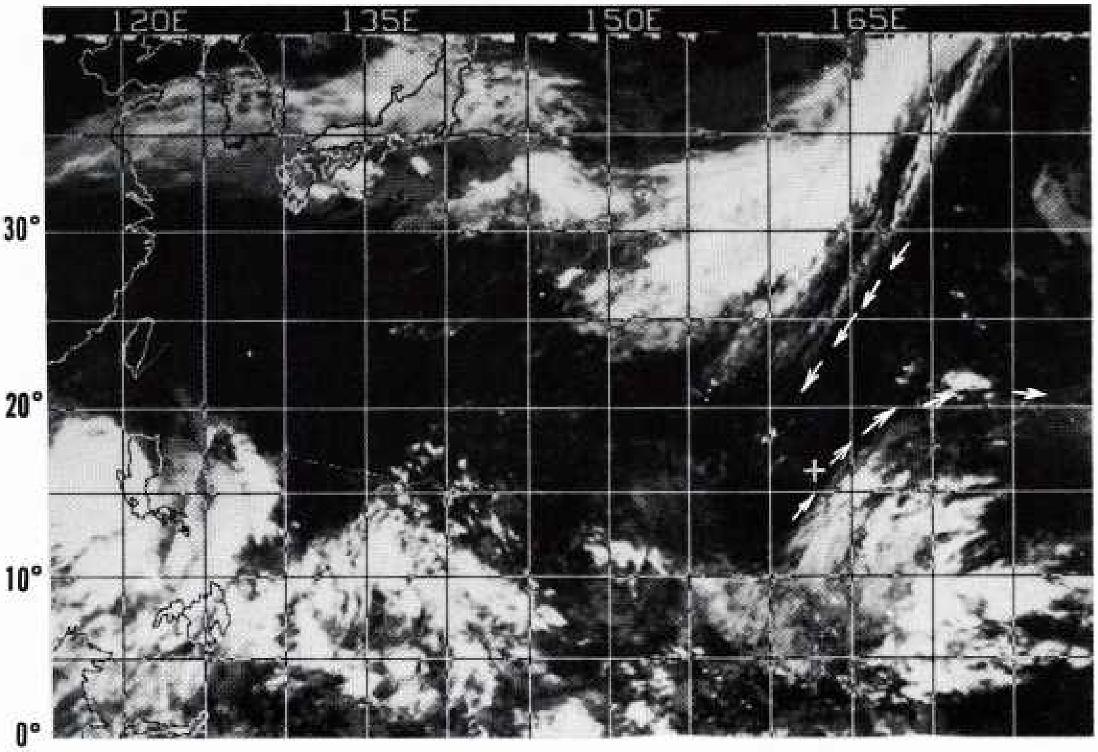

Figure 6. NOAA-1 IR mosaic near 1800 GMT on 15 June 1971.

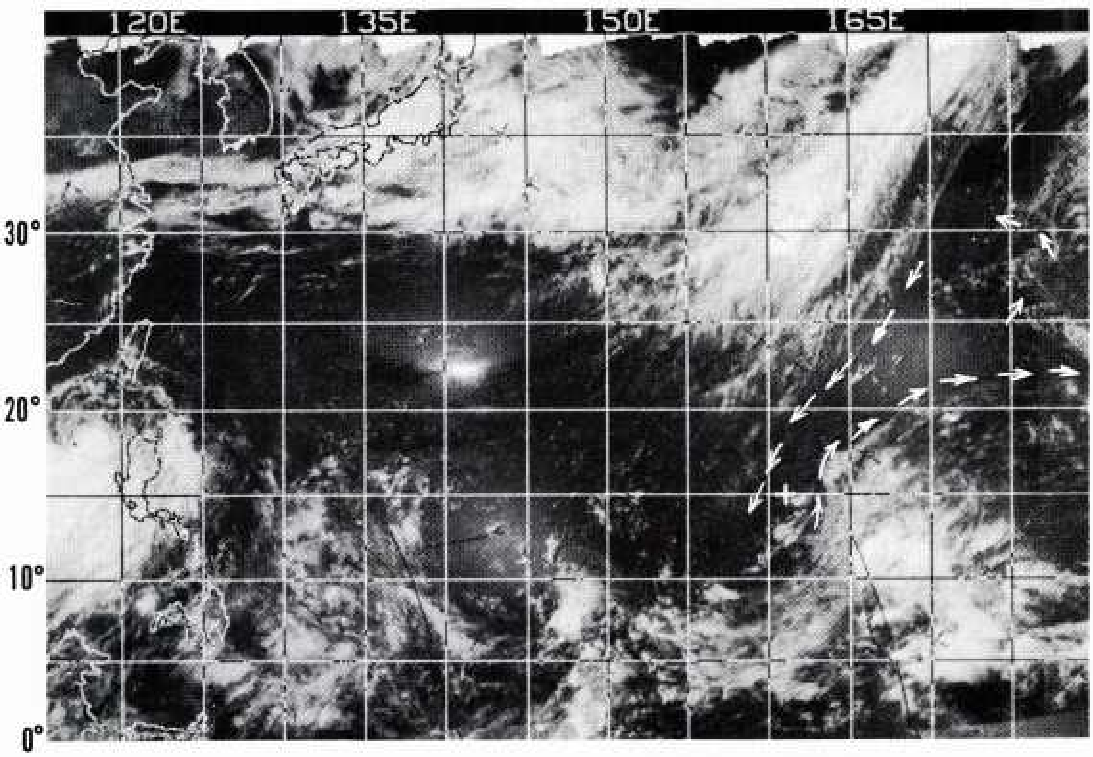

Figure 7. NOAA-1 AVCS mosaic near 0600 GMT on 16 June 1971.

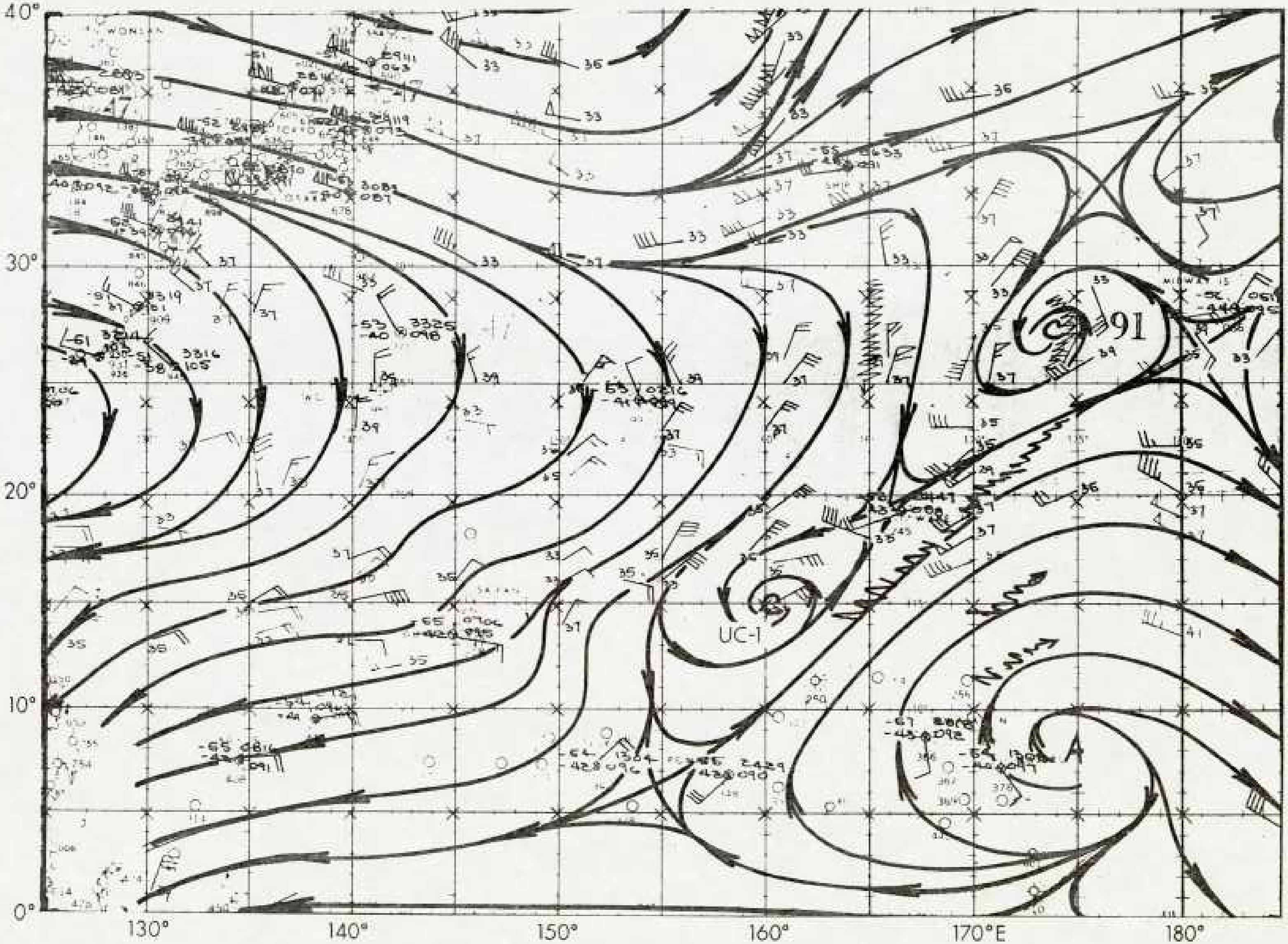

Figure 8. 250 mb analysis - 1200 GMT 17 June 1971.

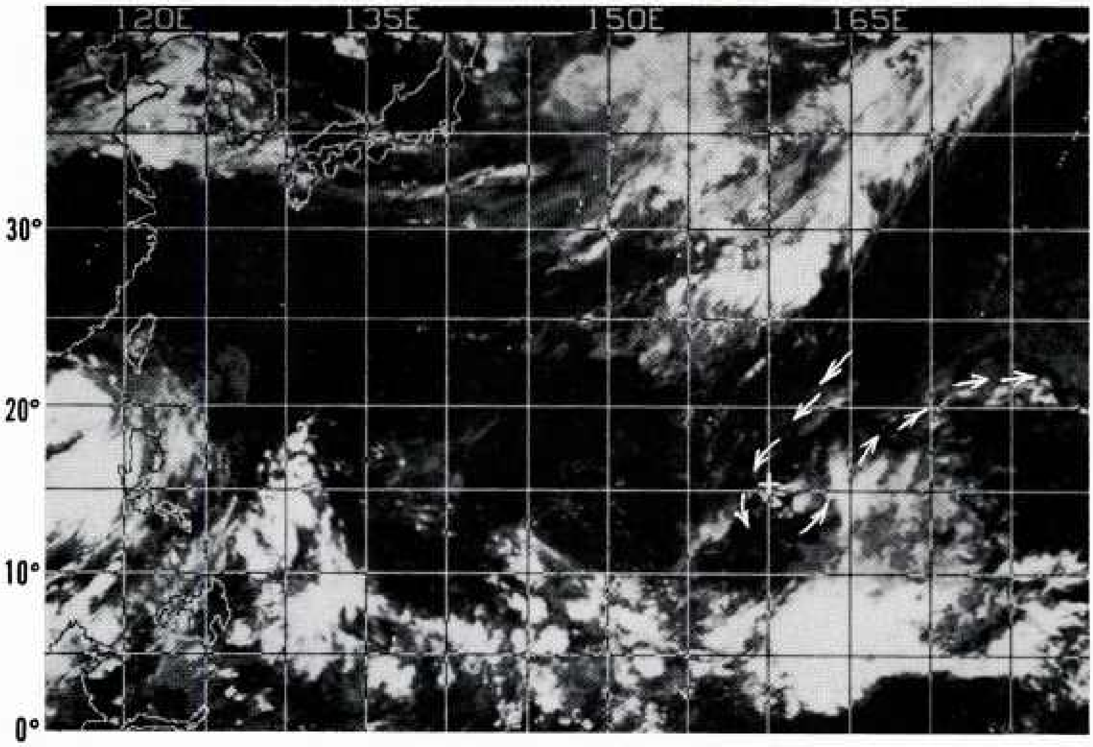

Figure 9. NOAA-1 IR mosaic near 1800 GMT on 16 June 1971.

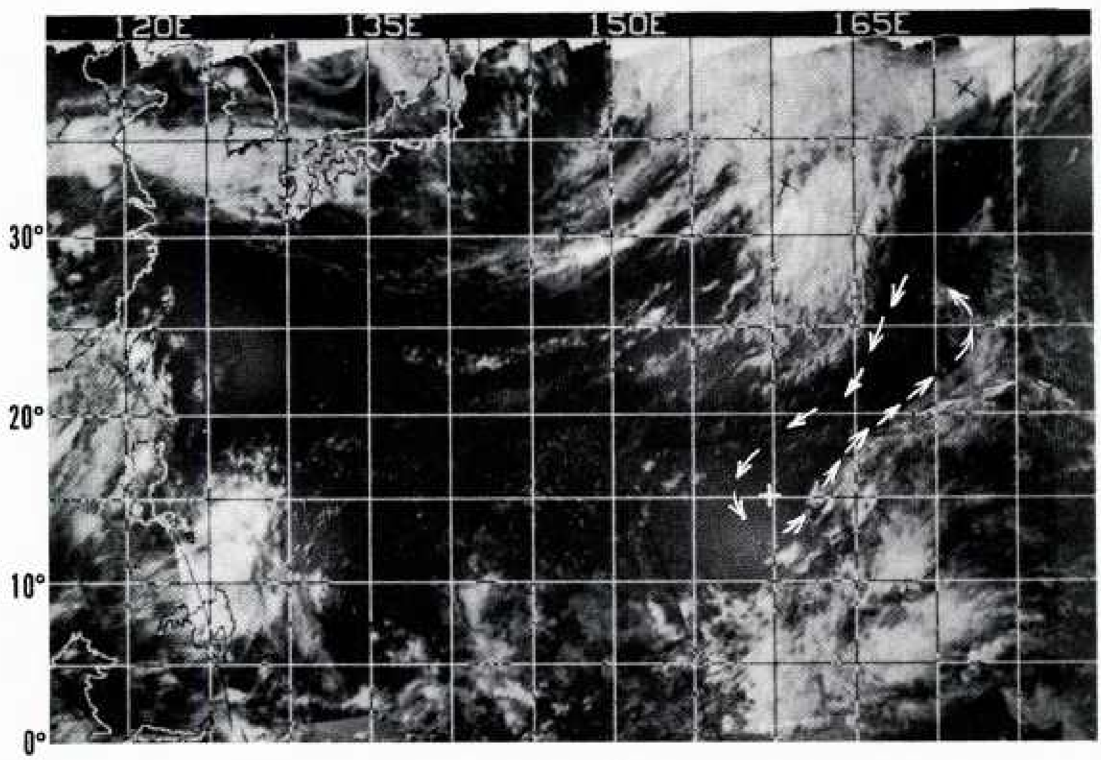

Figure 10. NOAA-1 AVCS mosaic near 0600 GMT on 17 June 1971.

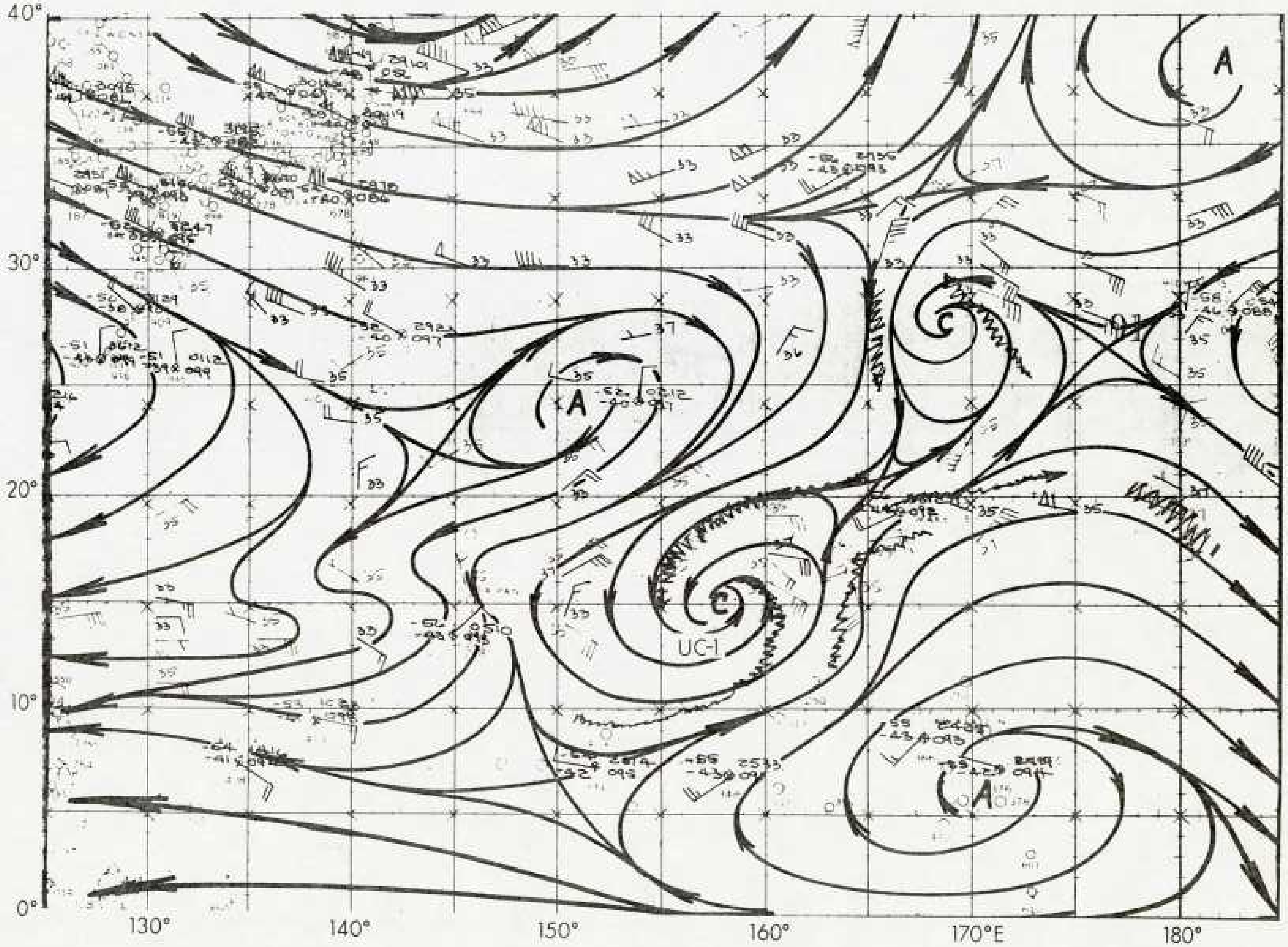

Figure 11. 250 mb analysis - 1200 GMT 18 June 1971.

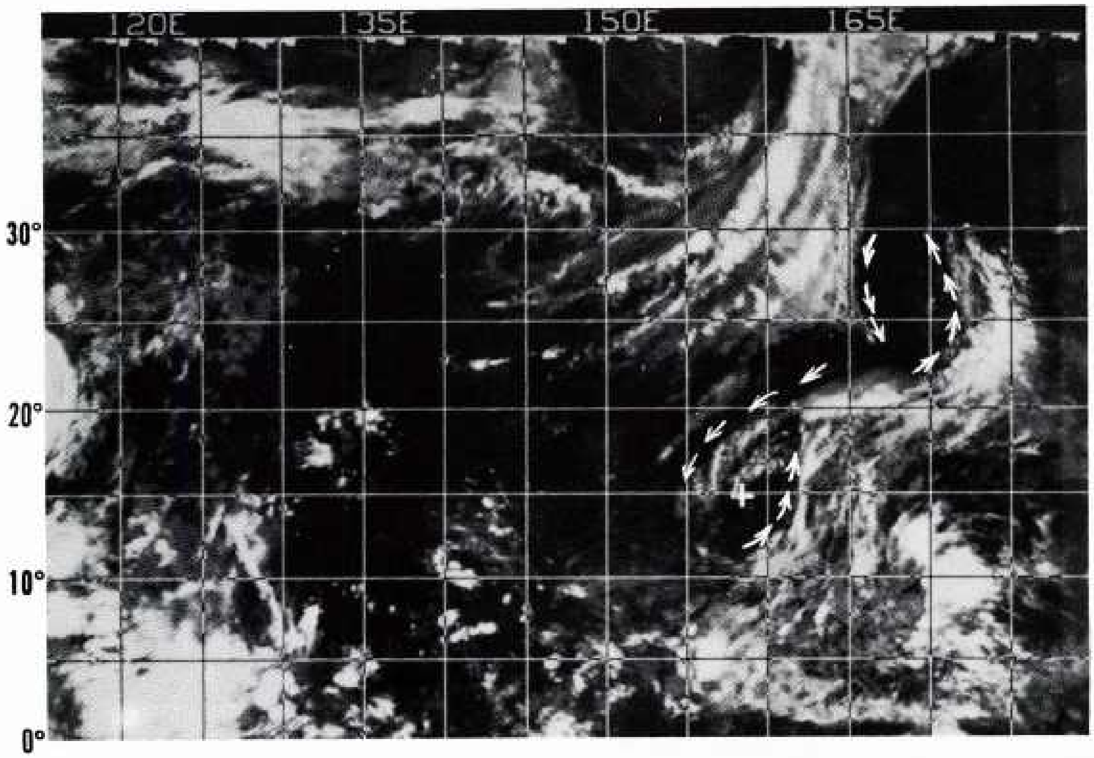

Figure 12. NOAA-1 IR mosaic near 1800 GMT on 17 June 1971.

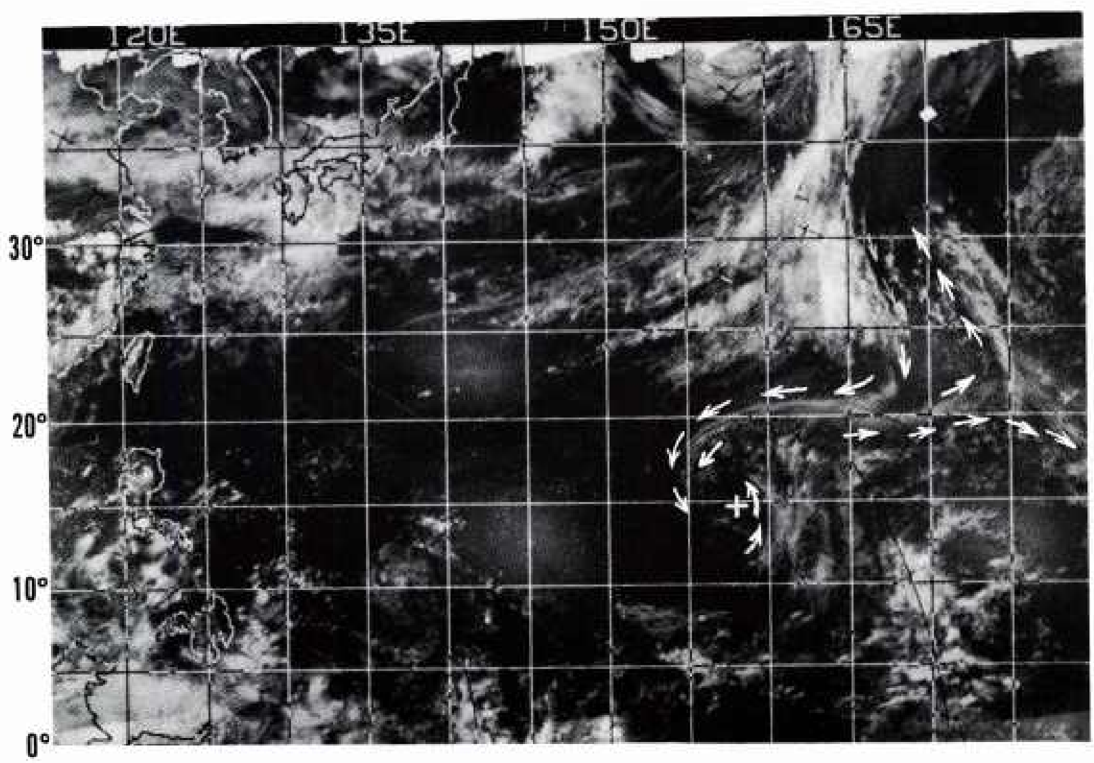

Figure 13. NOAA-1 AVCS mosaic near 0600 GMT on 18 June 1971.

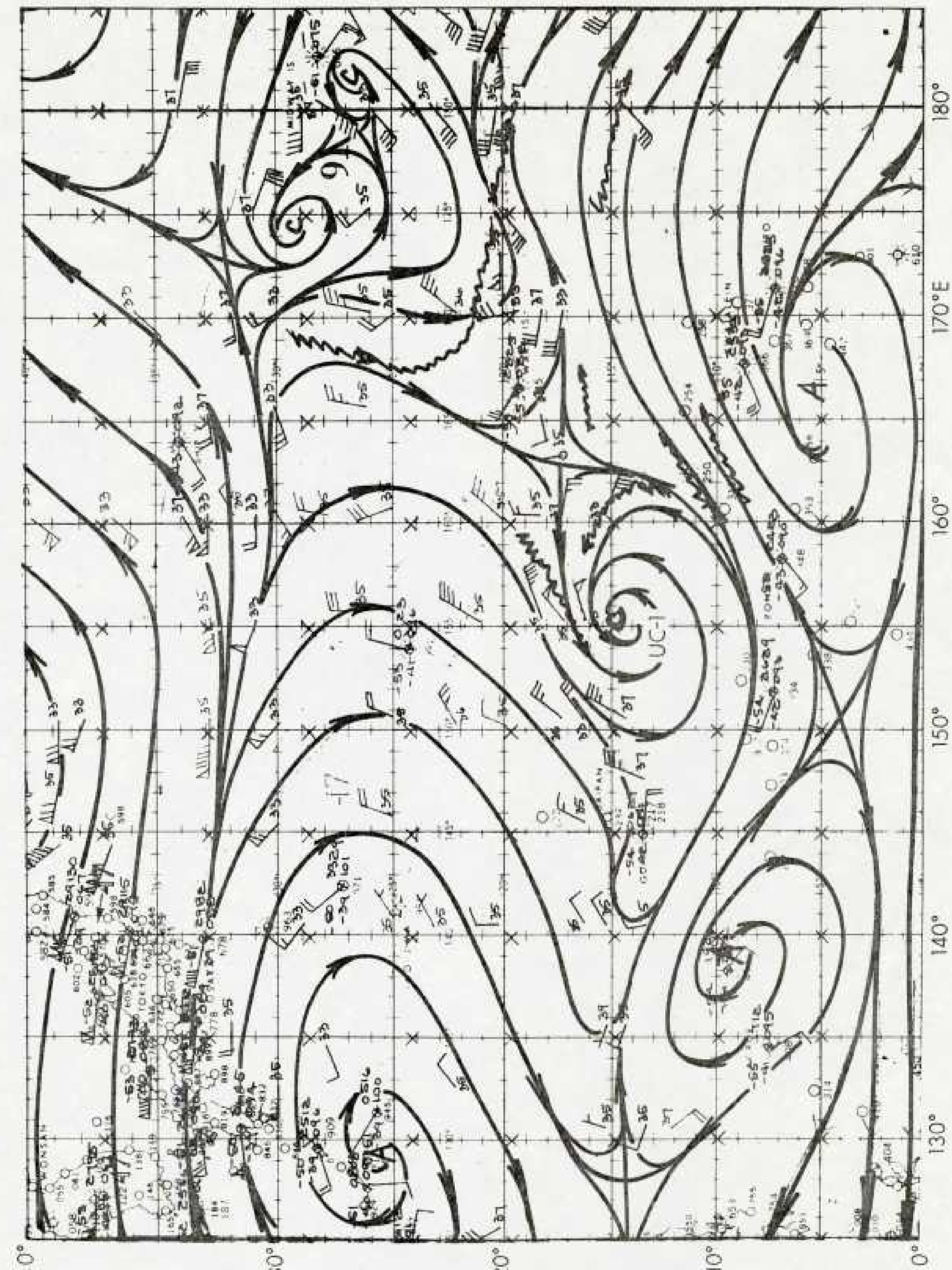

Figure 14. 250 mb analysis - 1200 GMT 19 June 1971.

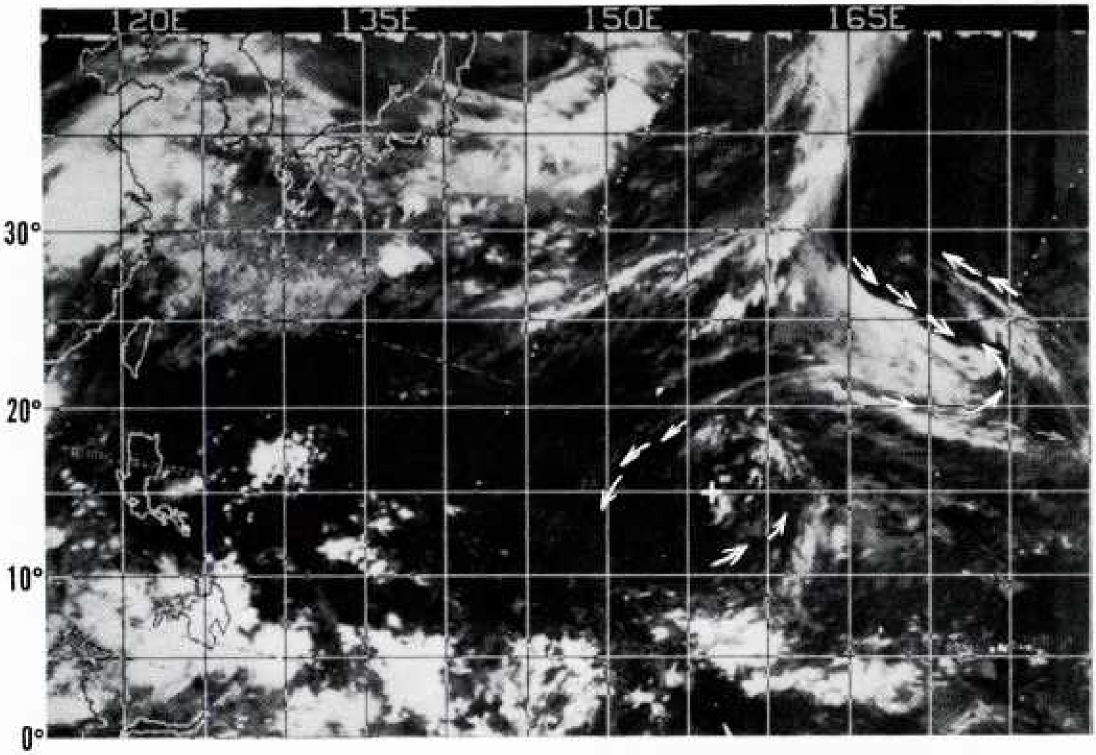

Figure 15. NOAA-1 IR mosaic near 1800 GMT on 18 June 1971.

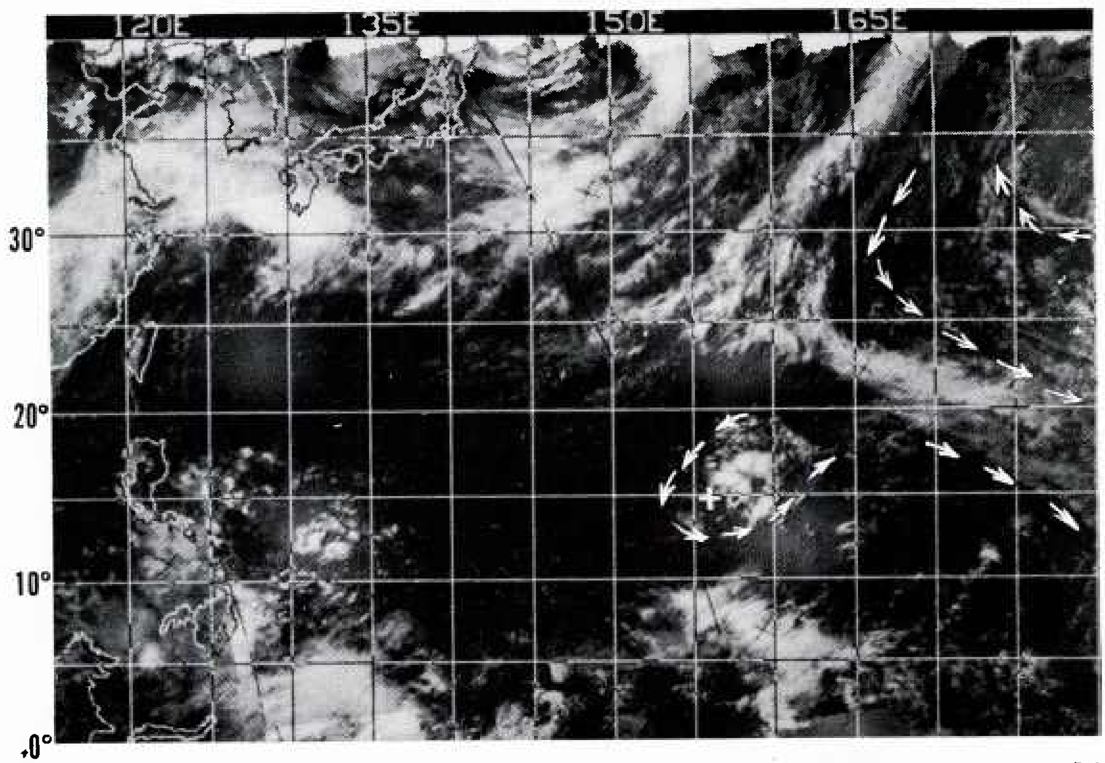

Figure 16. NOAA-1 AVCS mosaic near 0600 GMT on 19 June 1971.

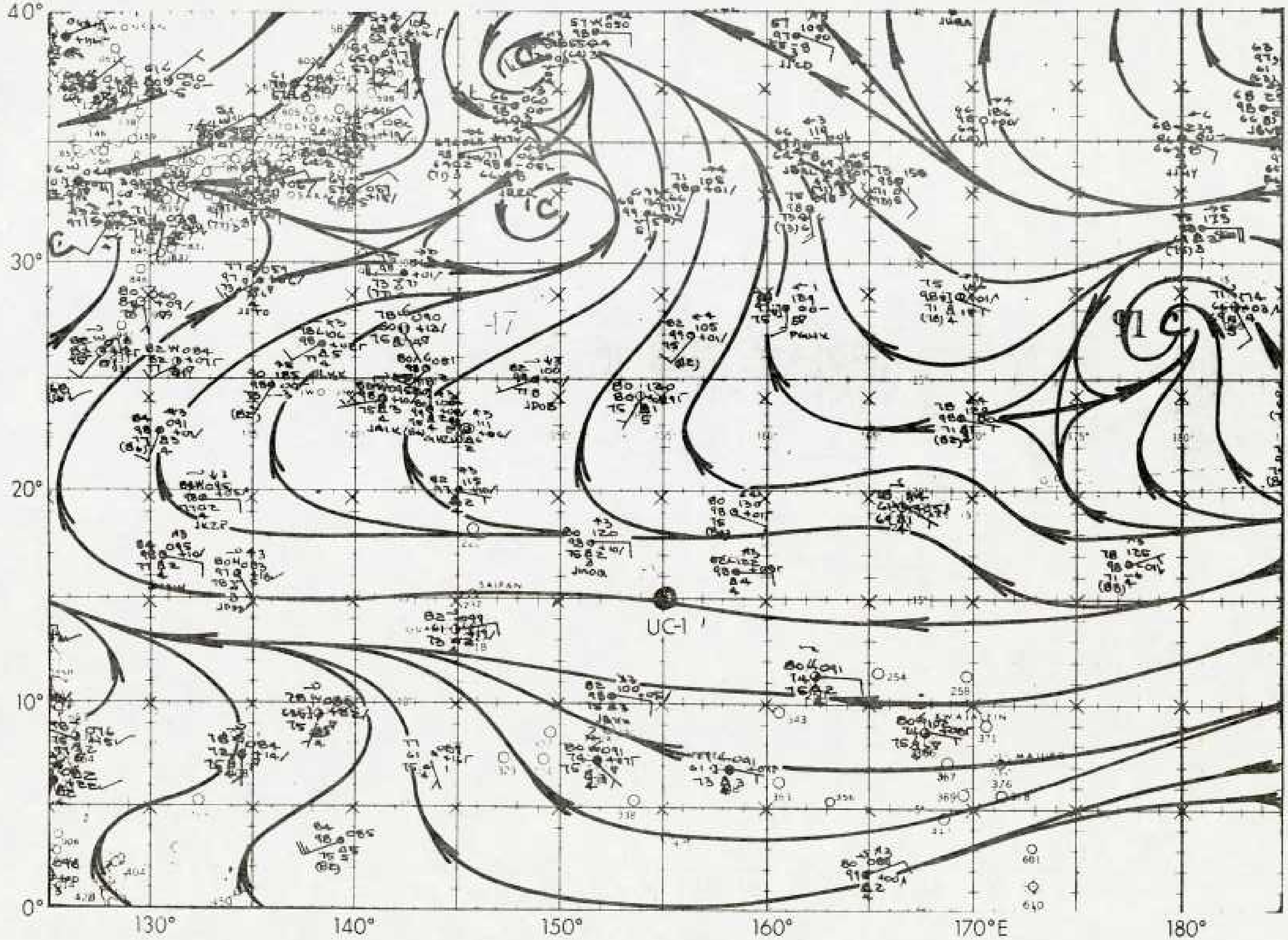

Figure 17. Surface wind analysis - 1200 GMT 19 June 1971.

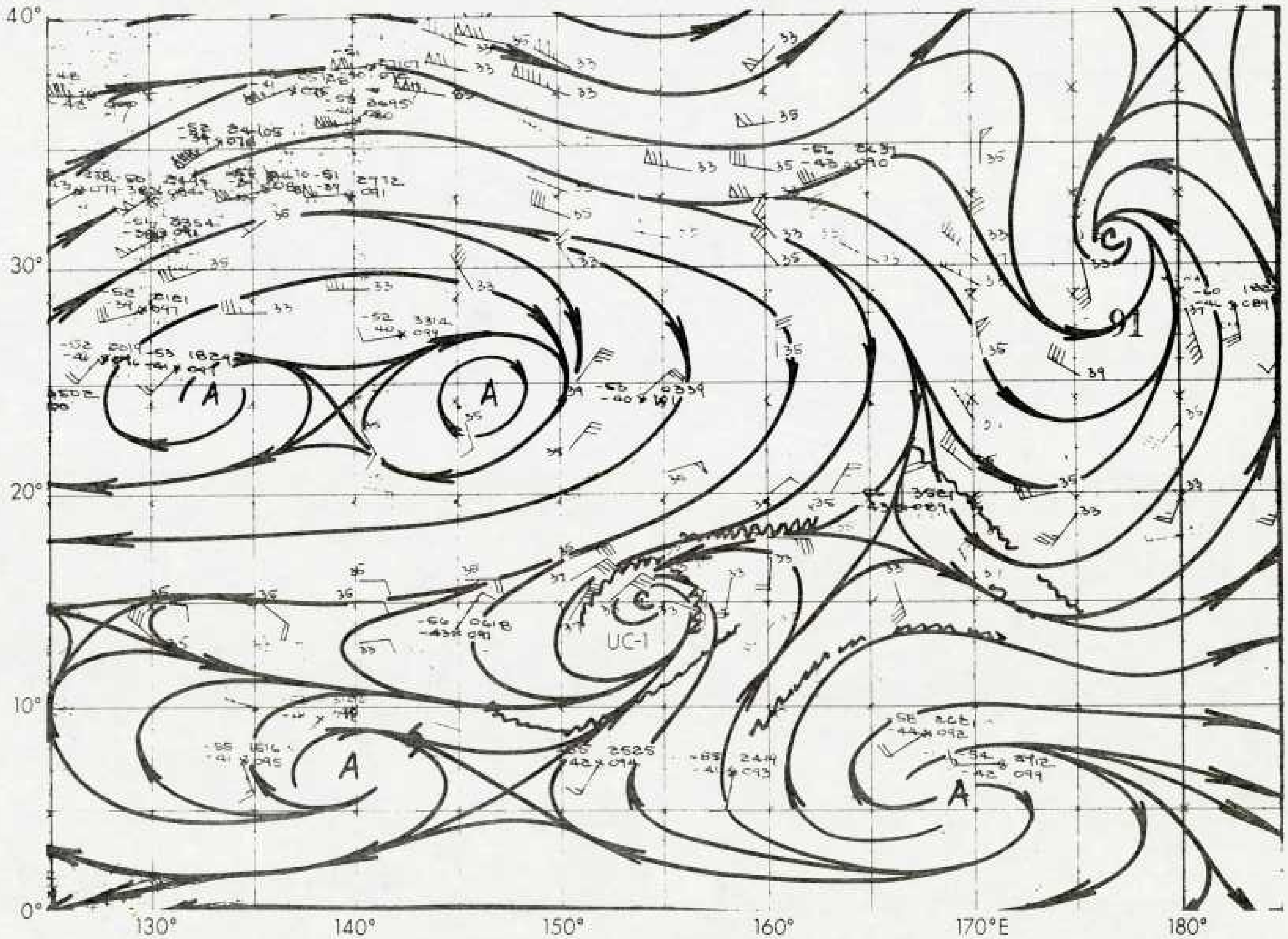

Figure 18. 250 mb analysis - 1200 GMT 20 June 1971.

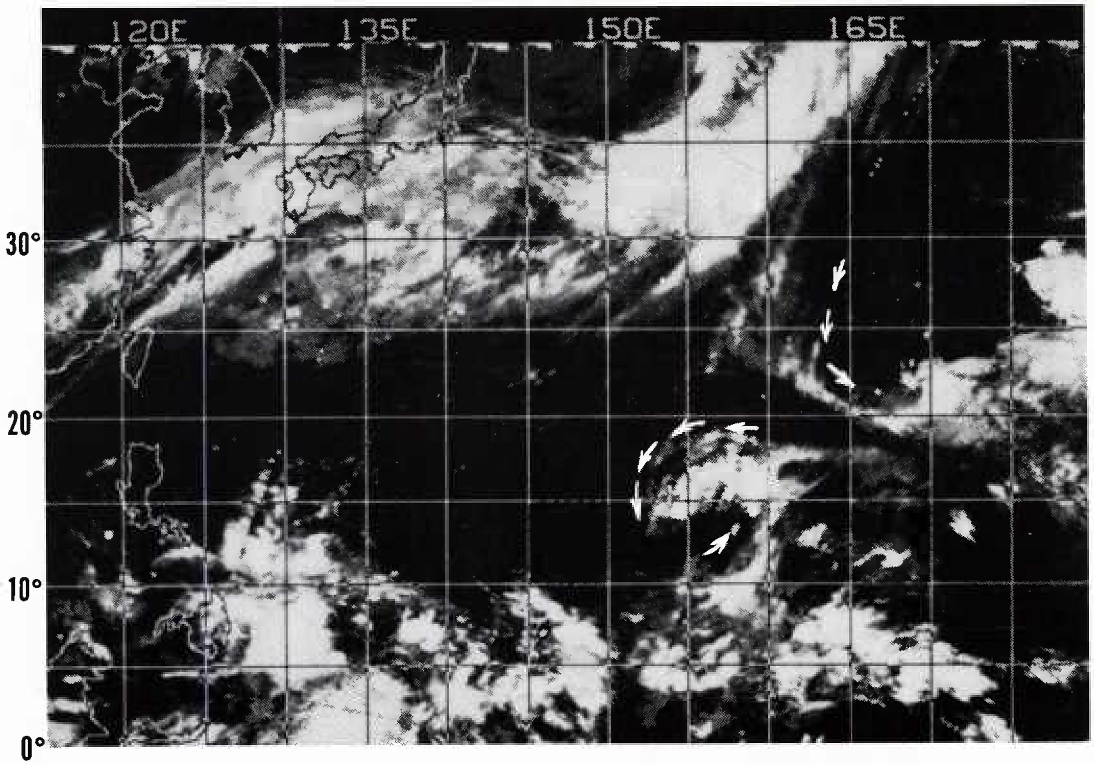

Figure 19. NOAA-1 IR mosaic near 1800 GMT on 19 June 1971.

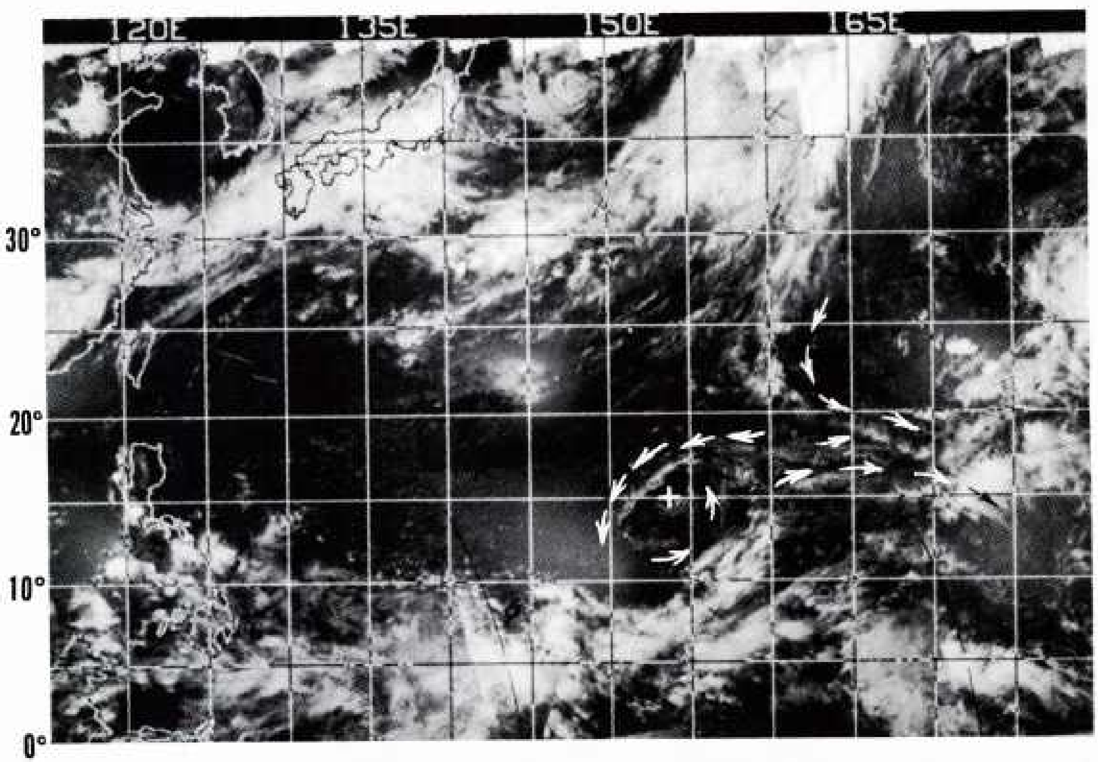

Figure 20. NOAA-1 AVCS mosaic near 0600 GMT on 20 June 1971.

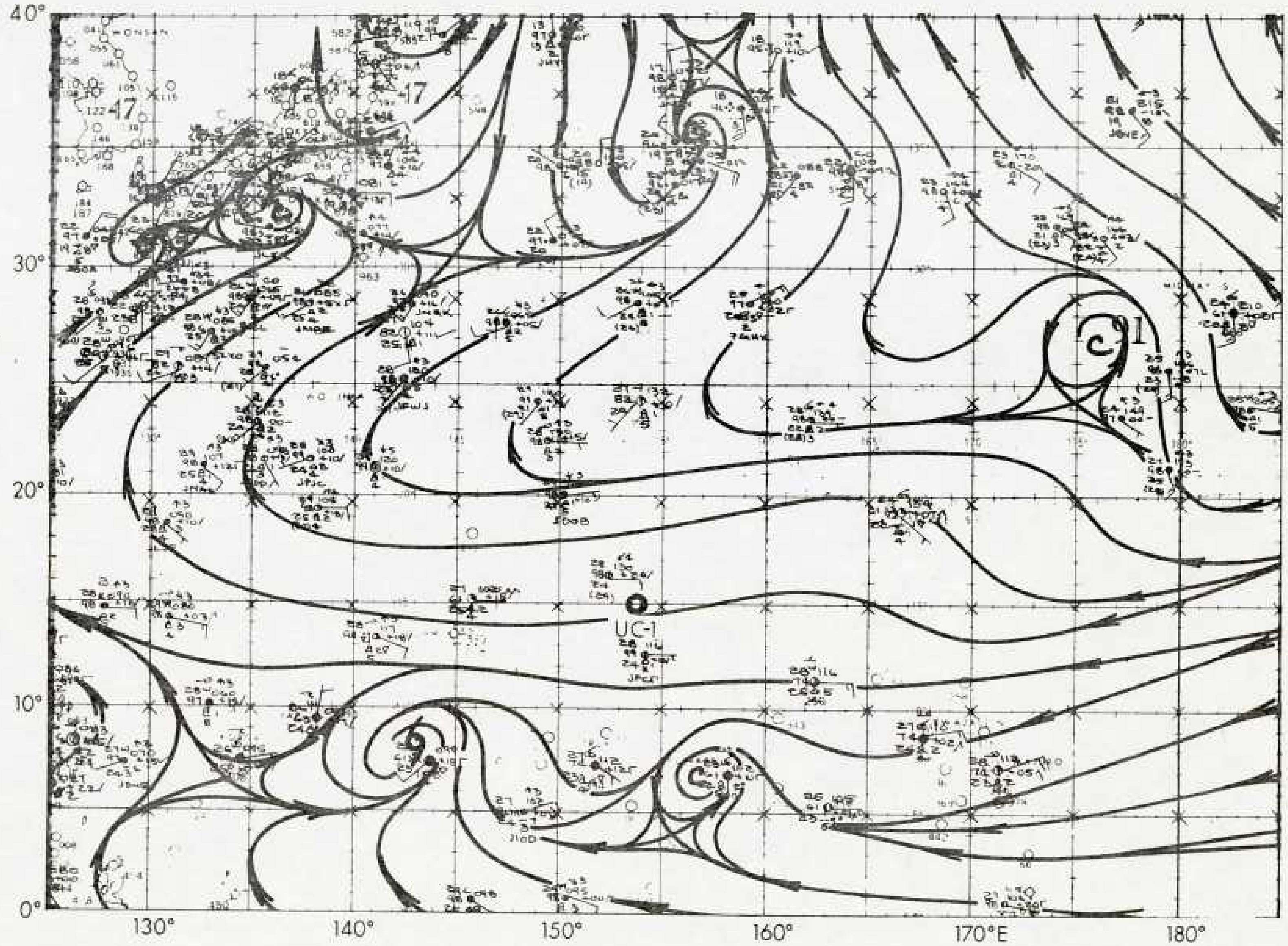

Figure 21. Surface wind analysis - 1200 GMT 20 June 1971.

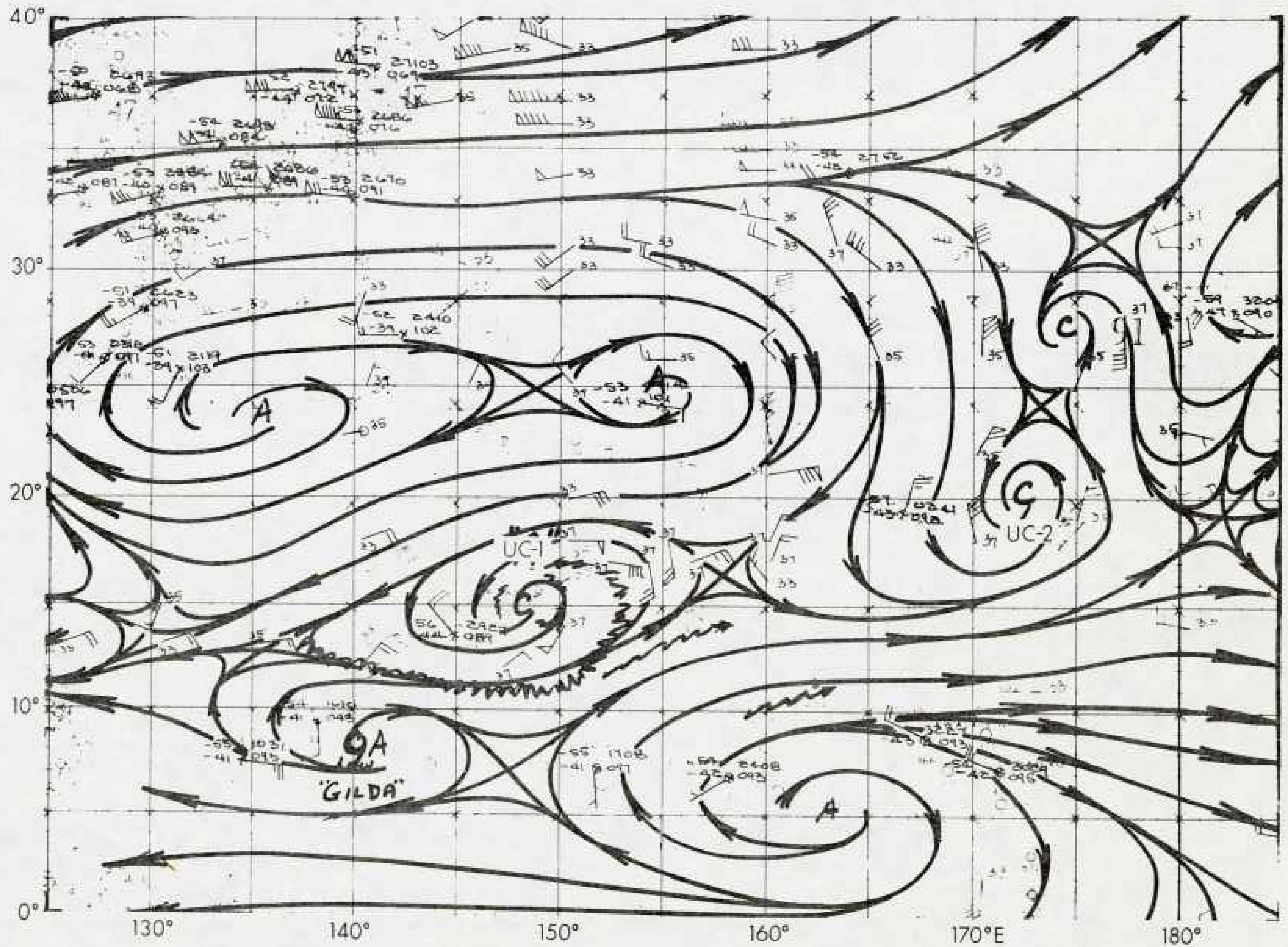

Figure 22. 250 mb analysis - 1200 GMT 21 June 1971.

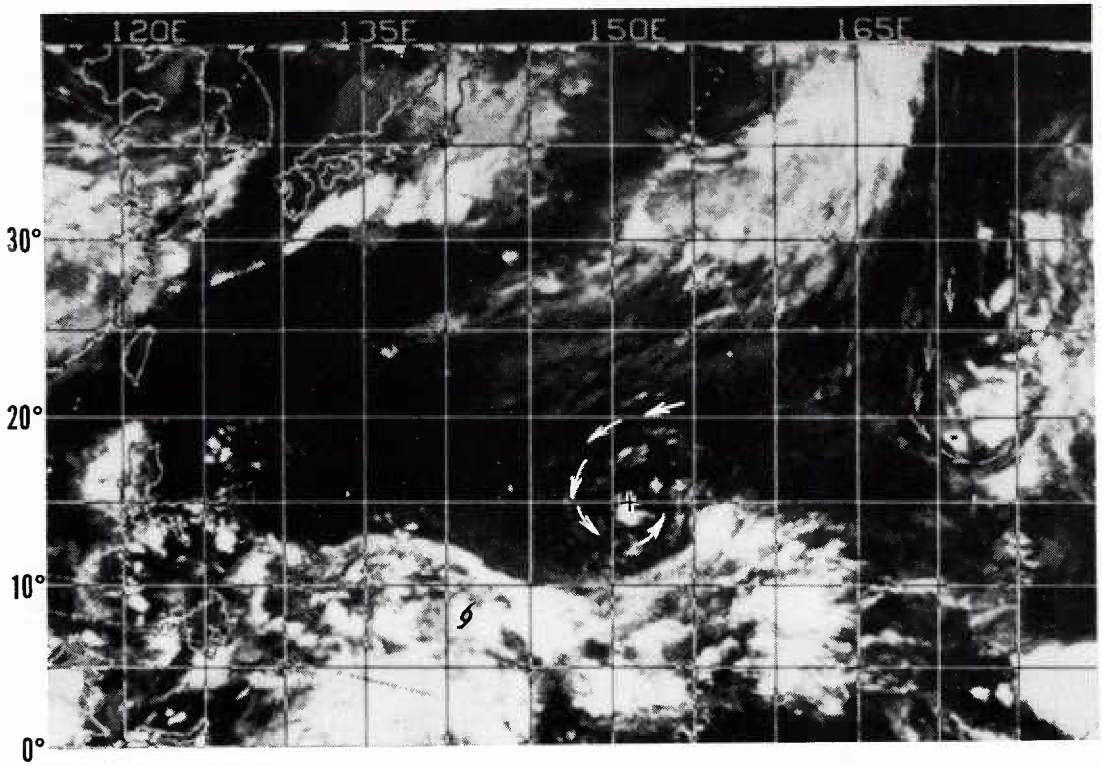

Figure 23. NOAA-1 IR mosaic near 1800 GMT on 20 June 1971.

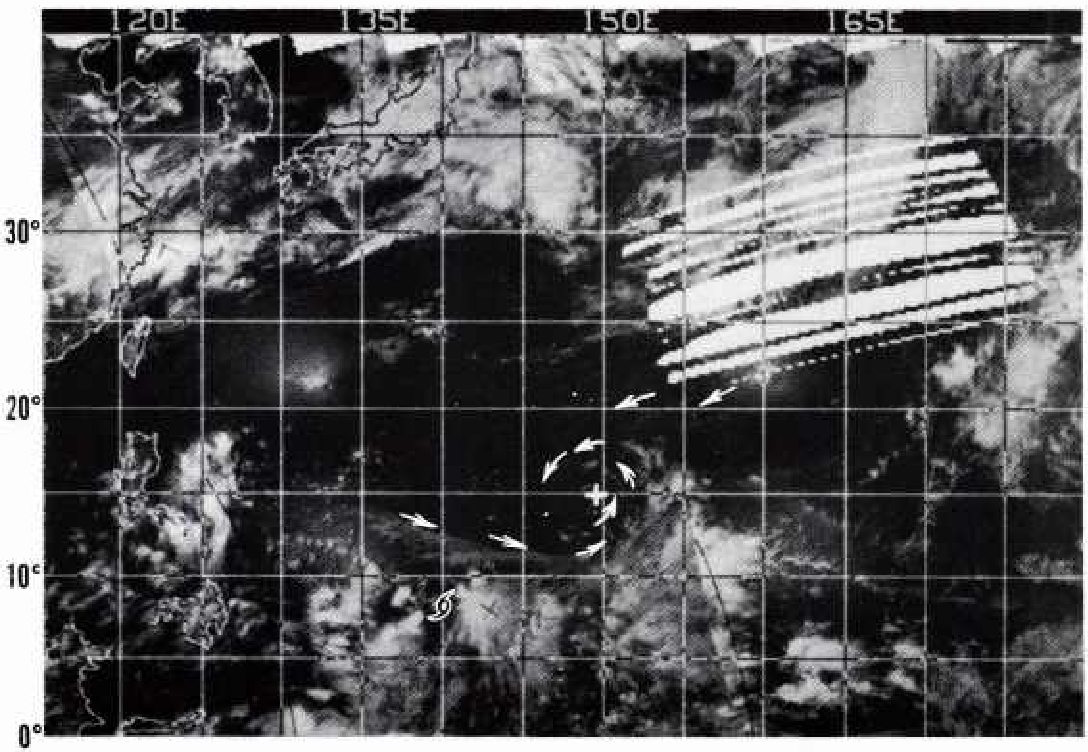

Figure 24. NOAA-1 AVCS mosaic near 0600 GMT on 21 June 1971.

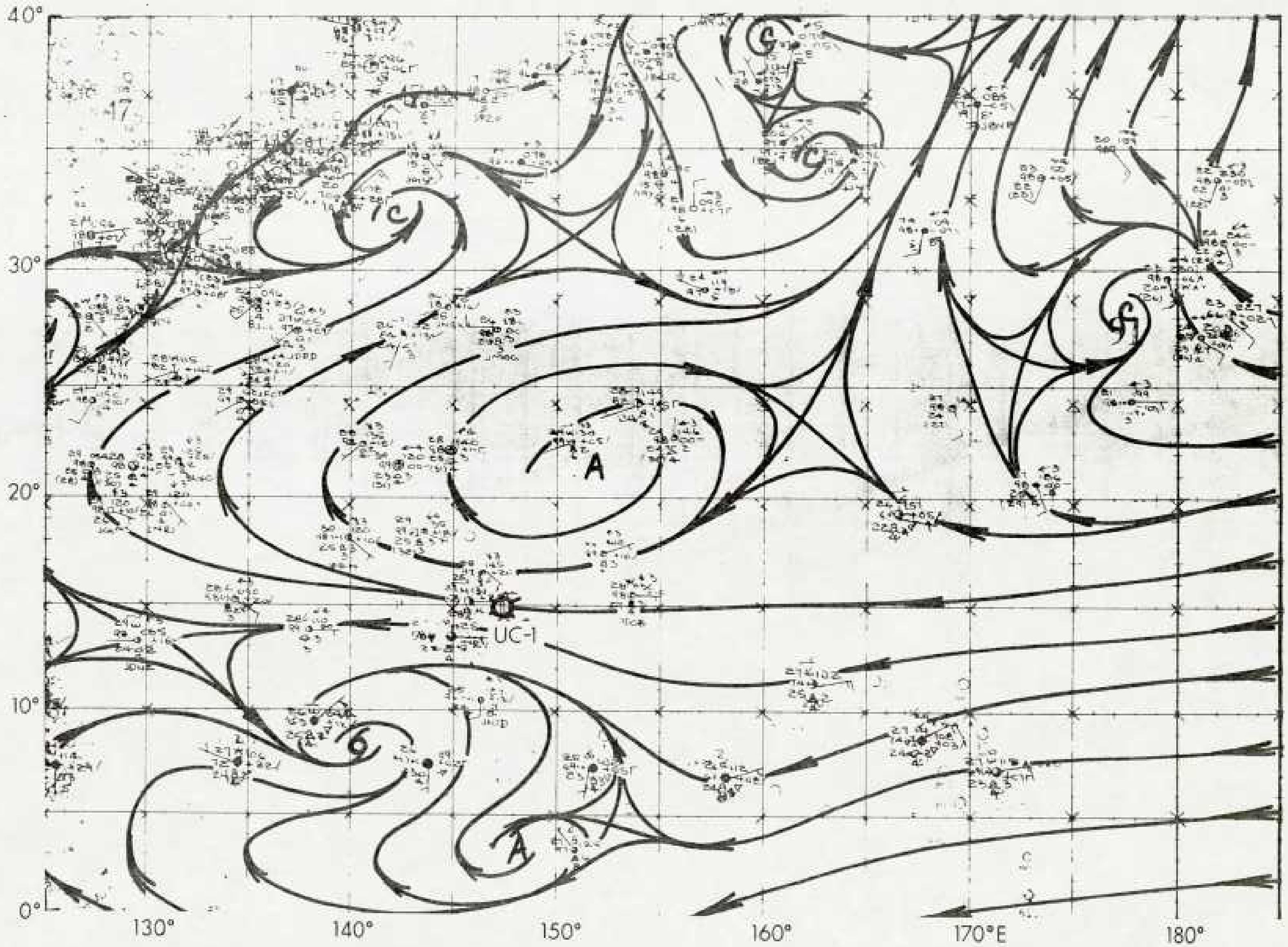

Figure 25. Surface wind analysis - 1200 GMT 21 June 1971.

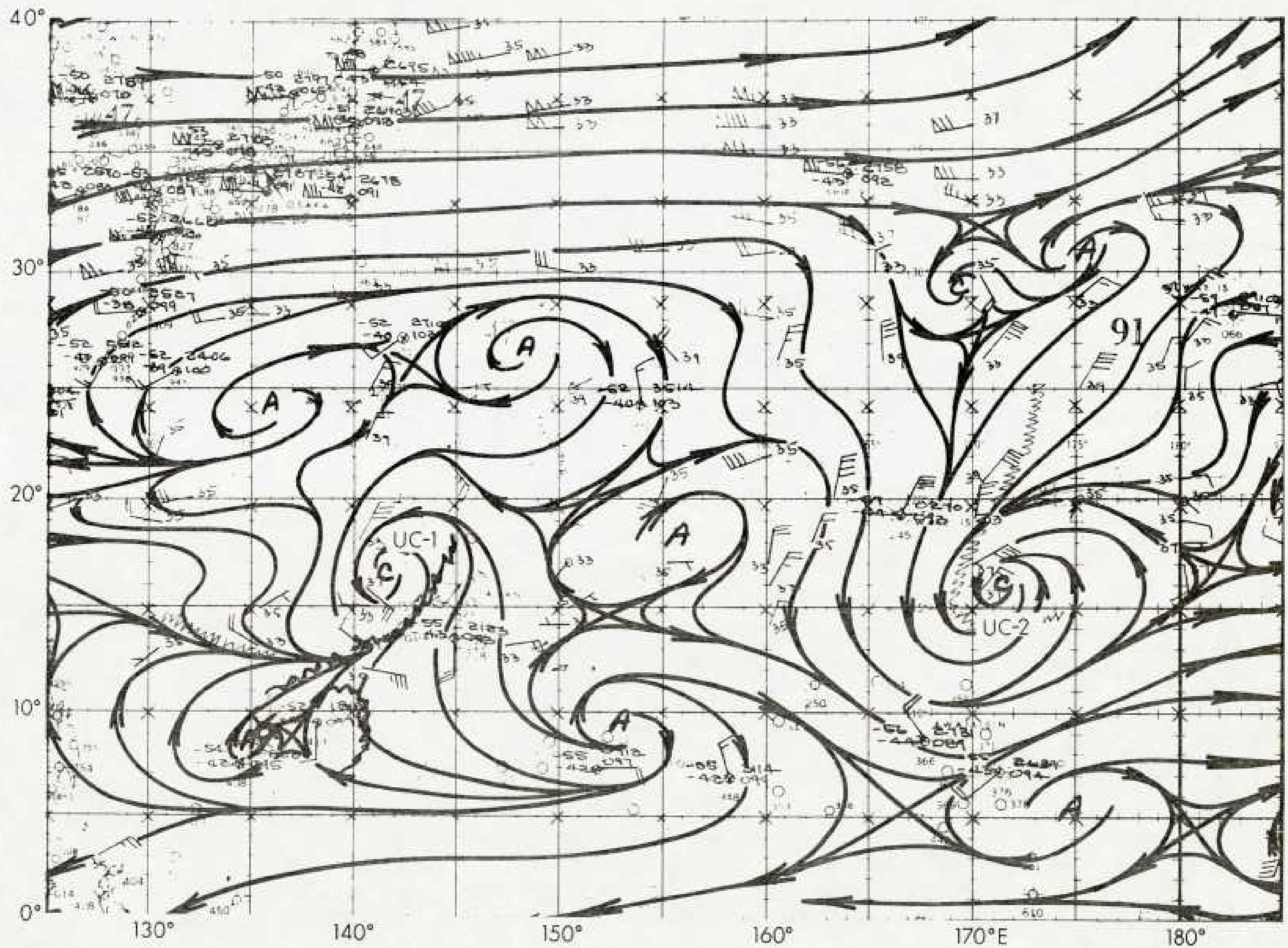

Figure 26. 250 mb analysis - 1200 GMT 22 June 1971.

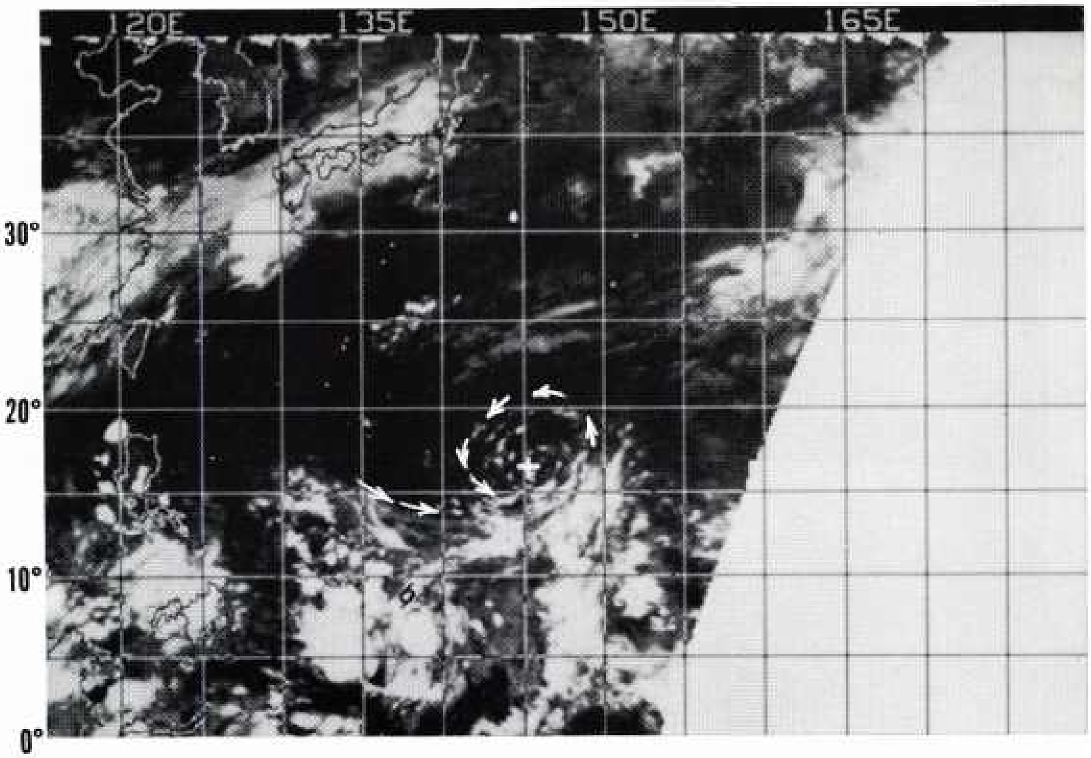

Figure 27. NOAA-1 IR mosaic near 1800 GMT on 21 June 1971.

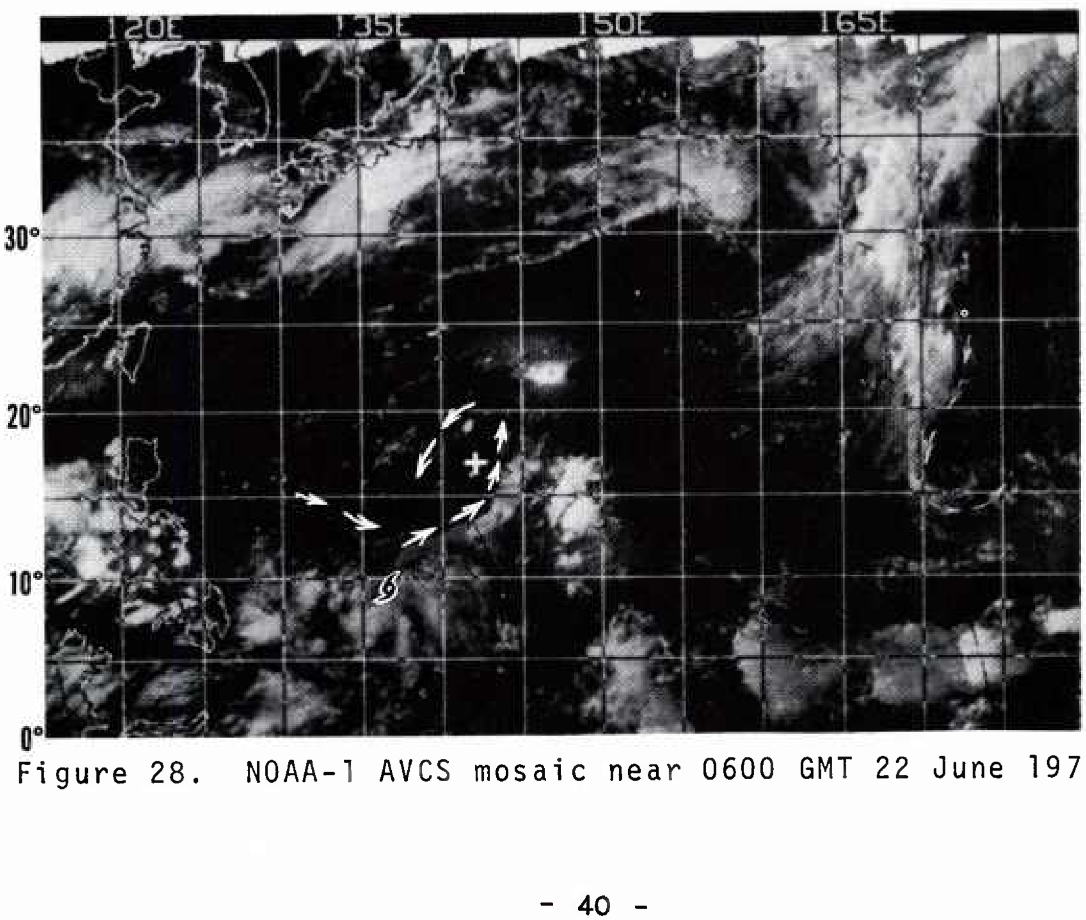

Figure 28. NOAA-1 AVCS mosaic near 0600 GMT 22 June 1971.

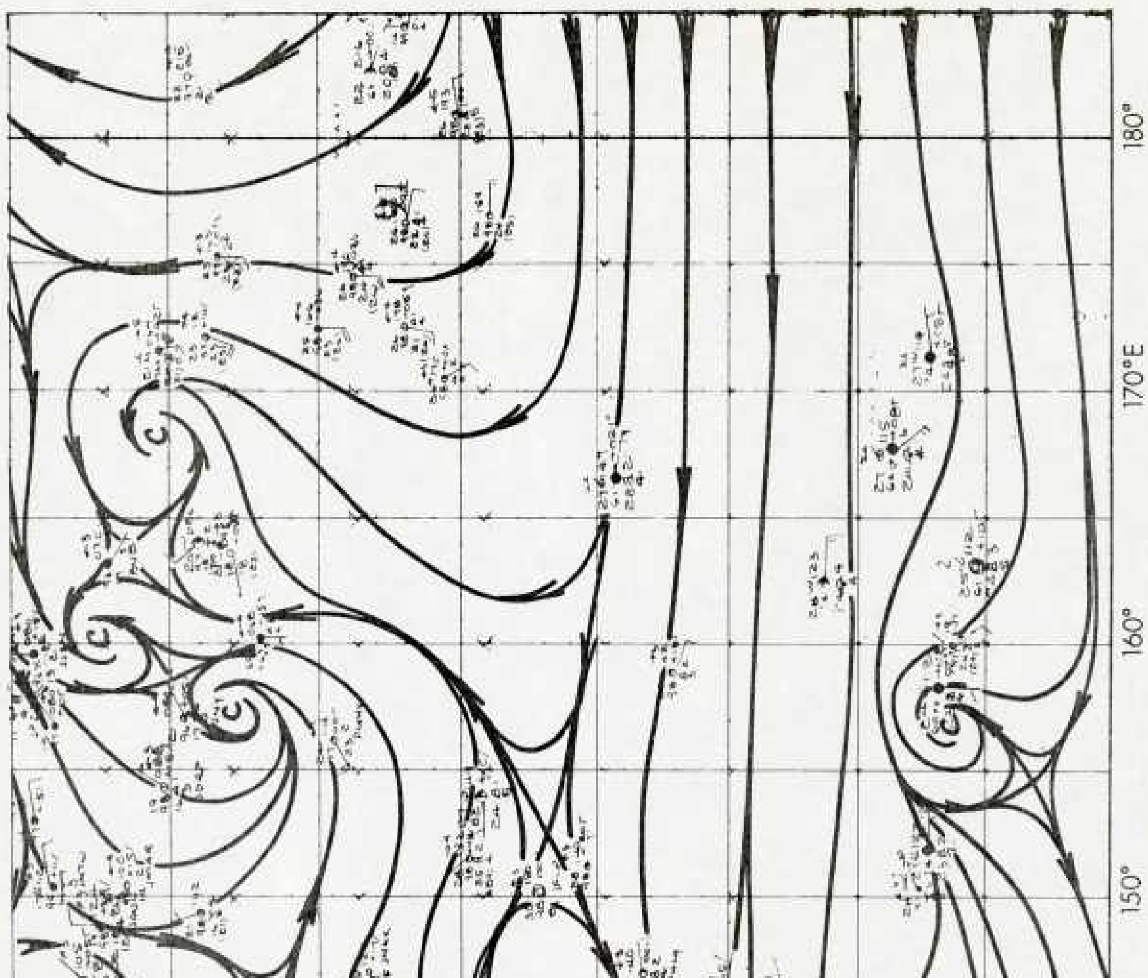

Figure 29. Surface wind analysis - 1200 GMT 22 June 1971.

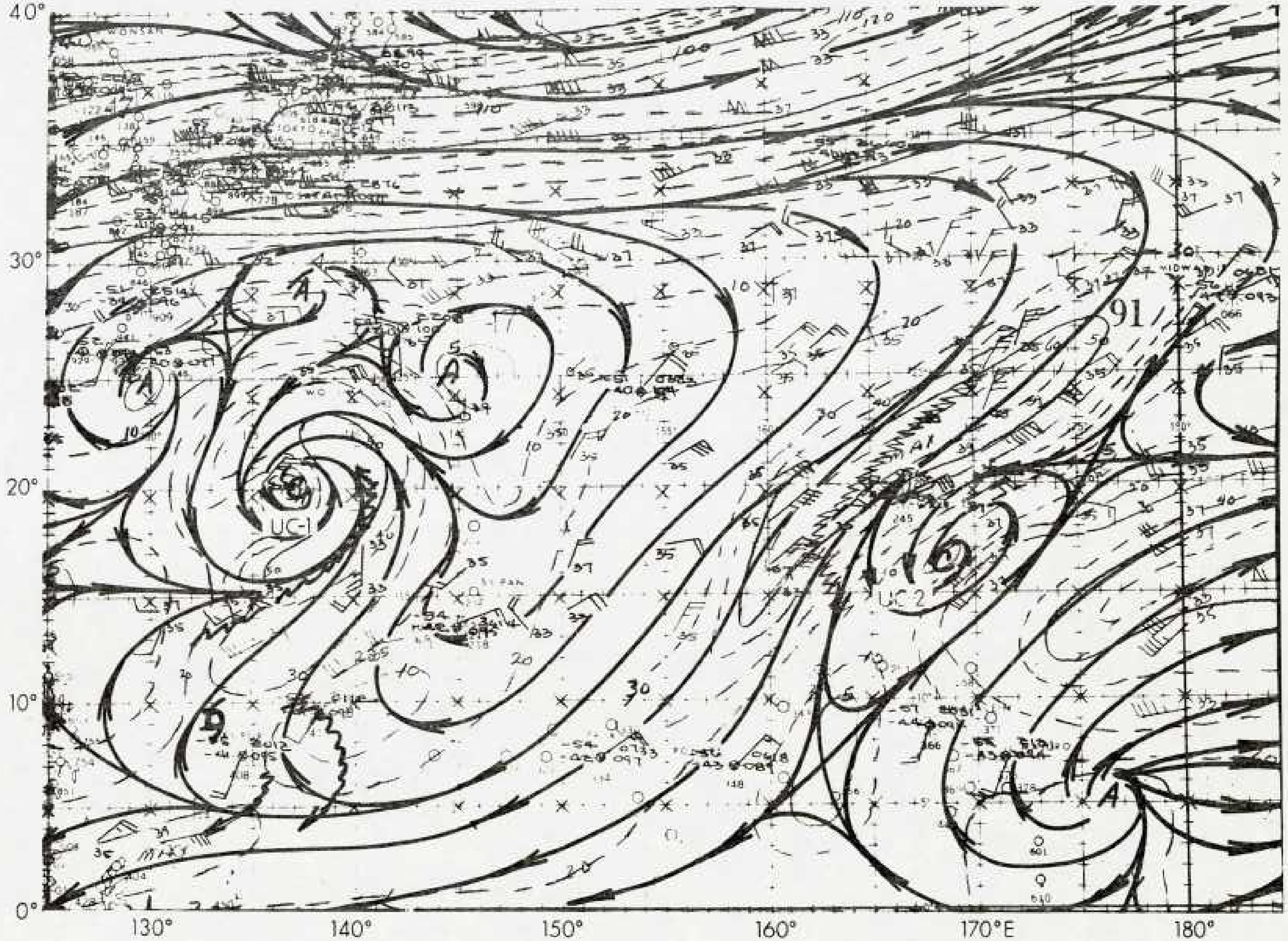

Figure 30. 250 mb analysis - 1200 GMT 23 June 1971.

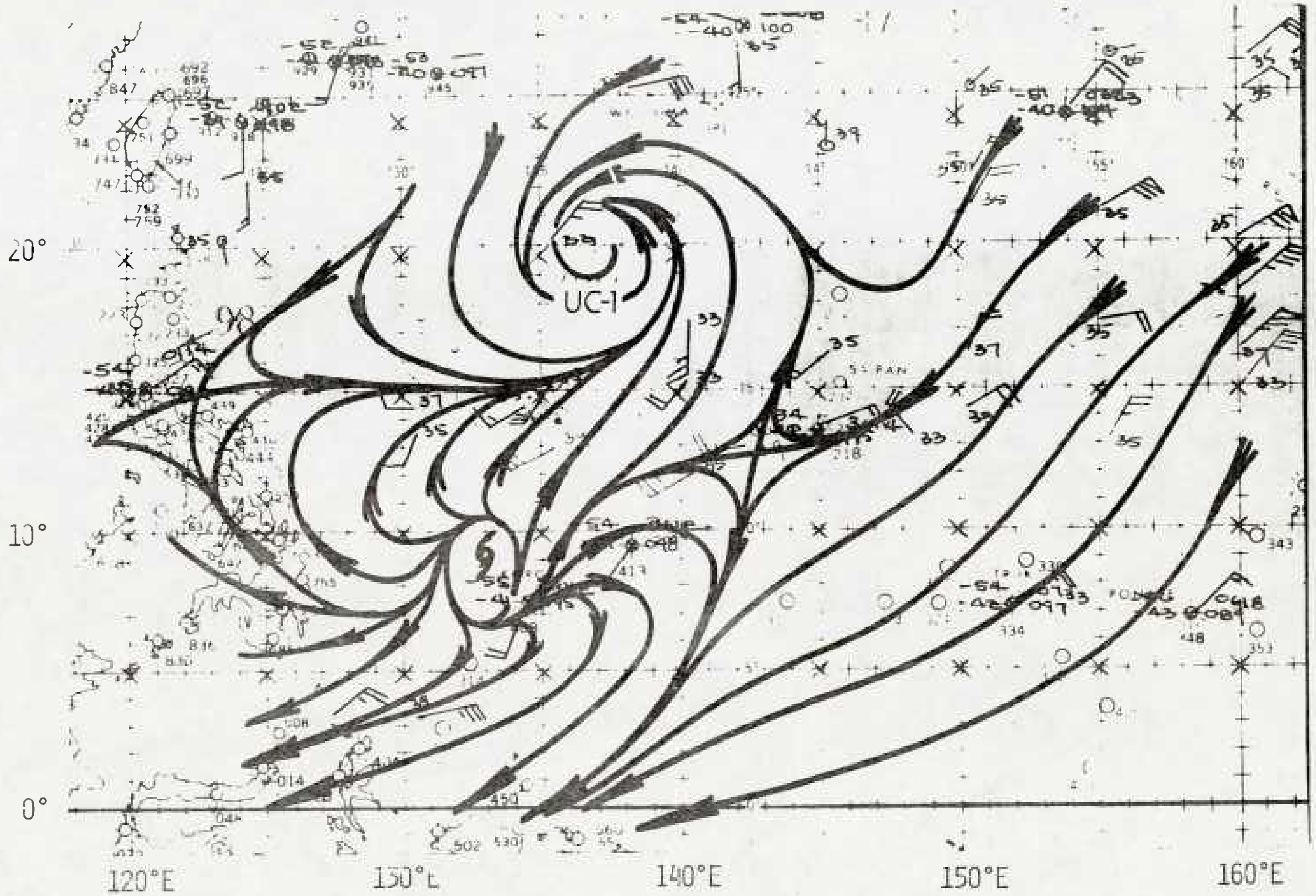

Figure 30a. Alternate 250 mb analysis for 1200 GMT 23 june 1971.

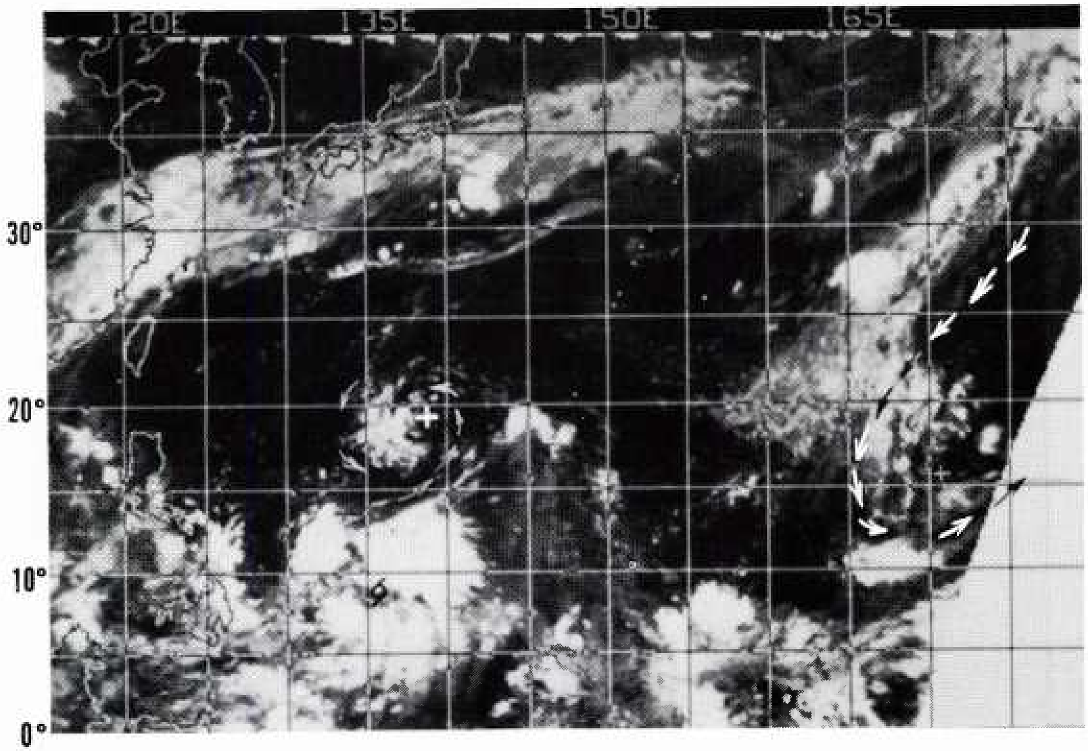

Figure 31. NOAA-1 IR mosaic near 1800 GMT on 22 June 1971.

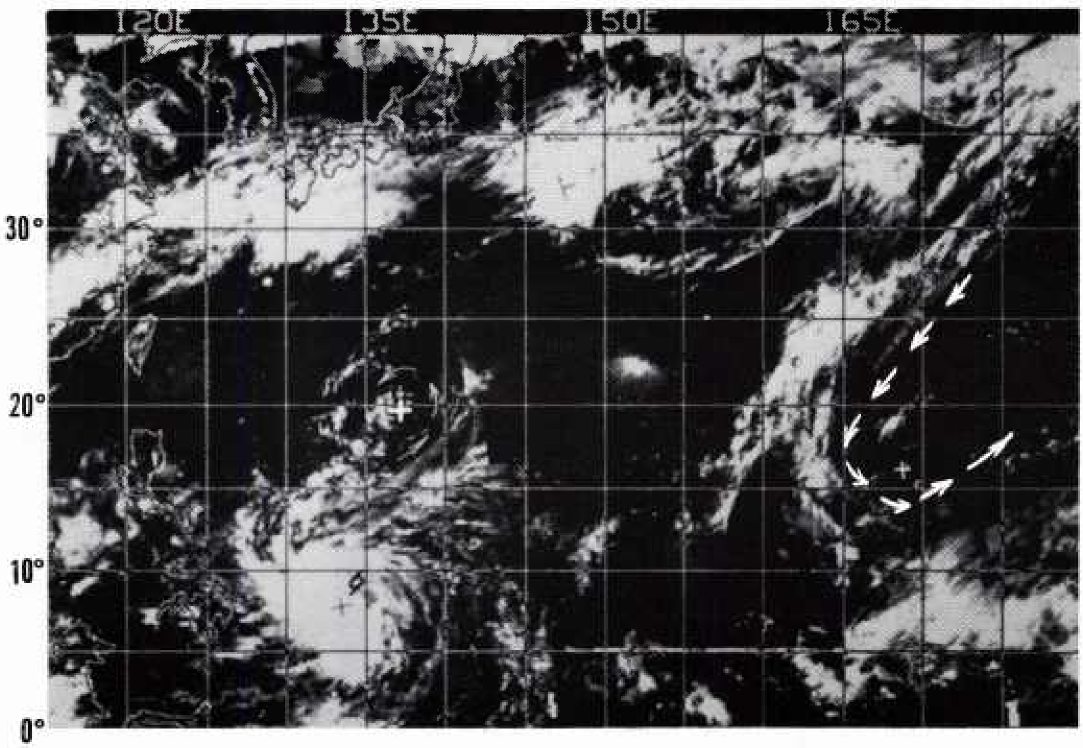

Figure 32. NOAA-1 AVCS mosaic near 0600 GMT on 23 June 1971.

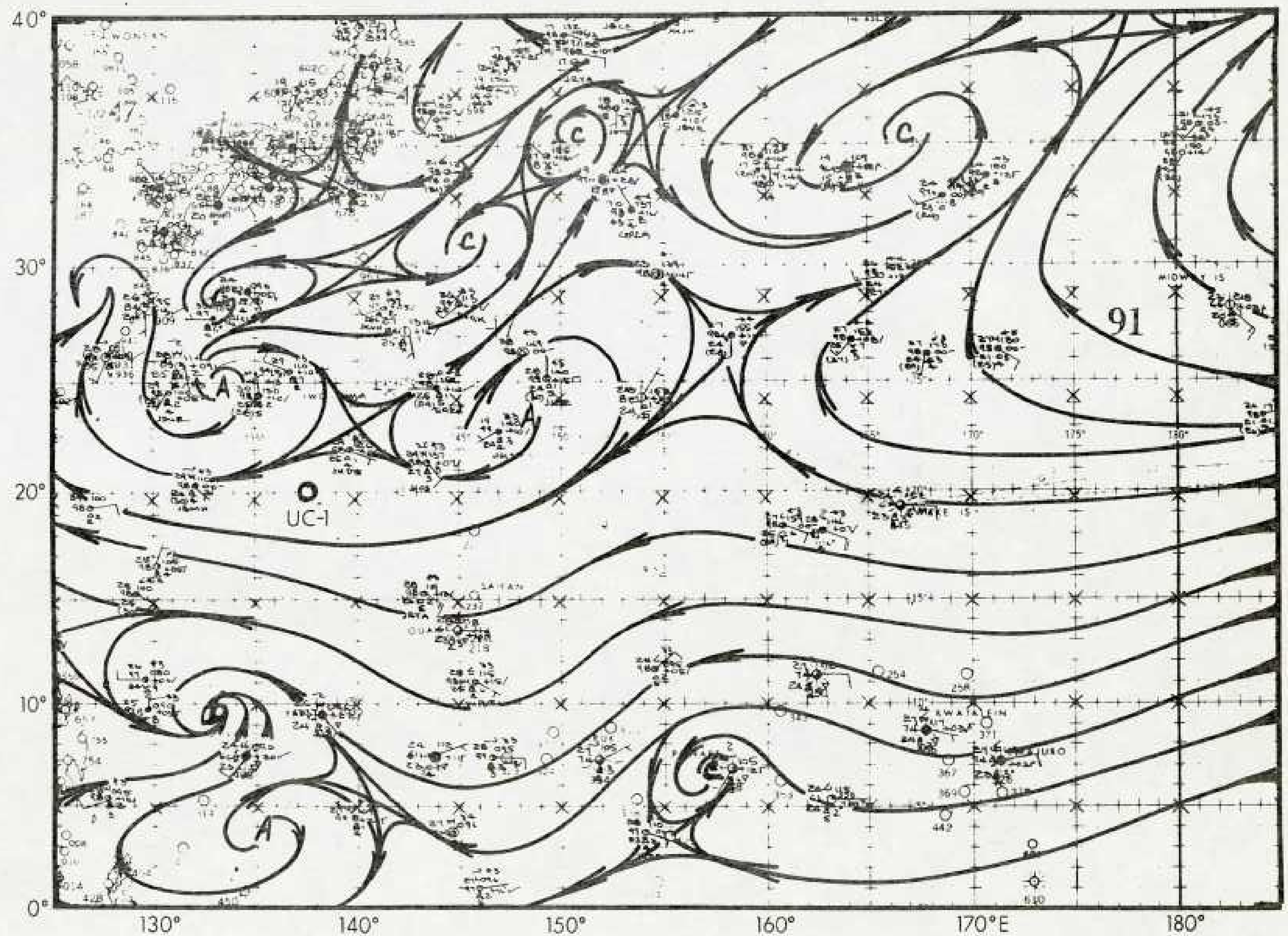

Figure 33. Surface wind analysis - 1200 GMT 23 June 1971.

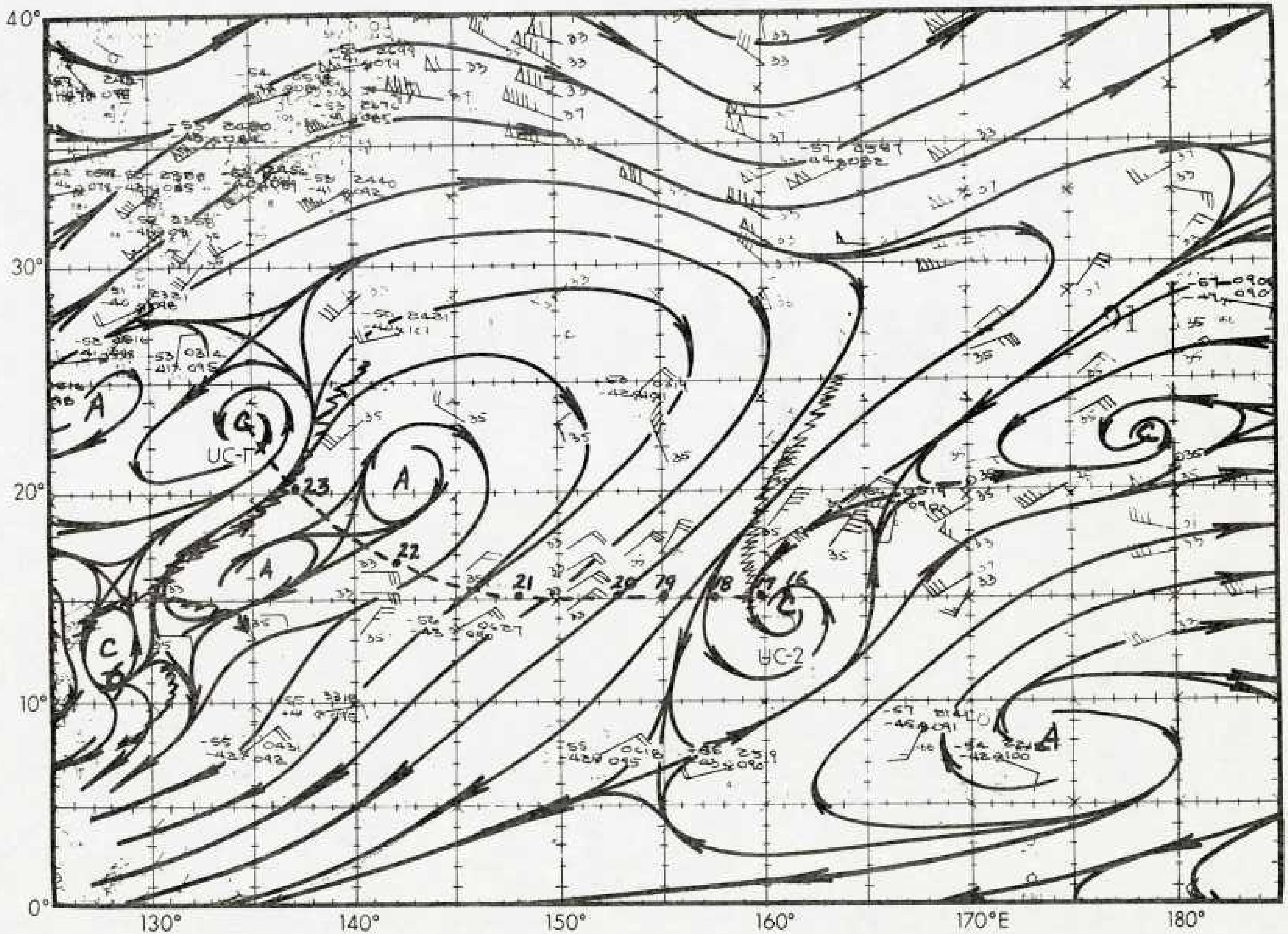

Figure 34. 250 mb analysis - 1200 GMT 24 June 1971.

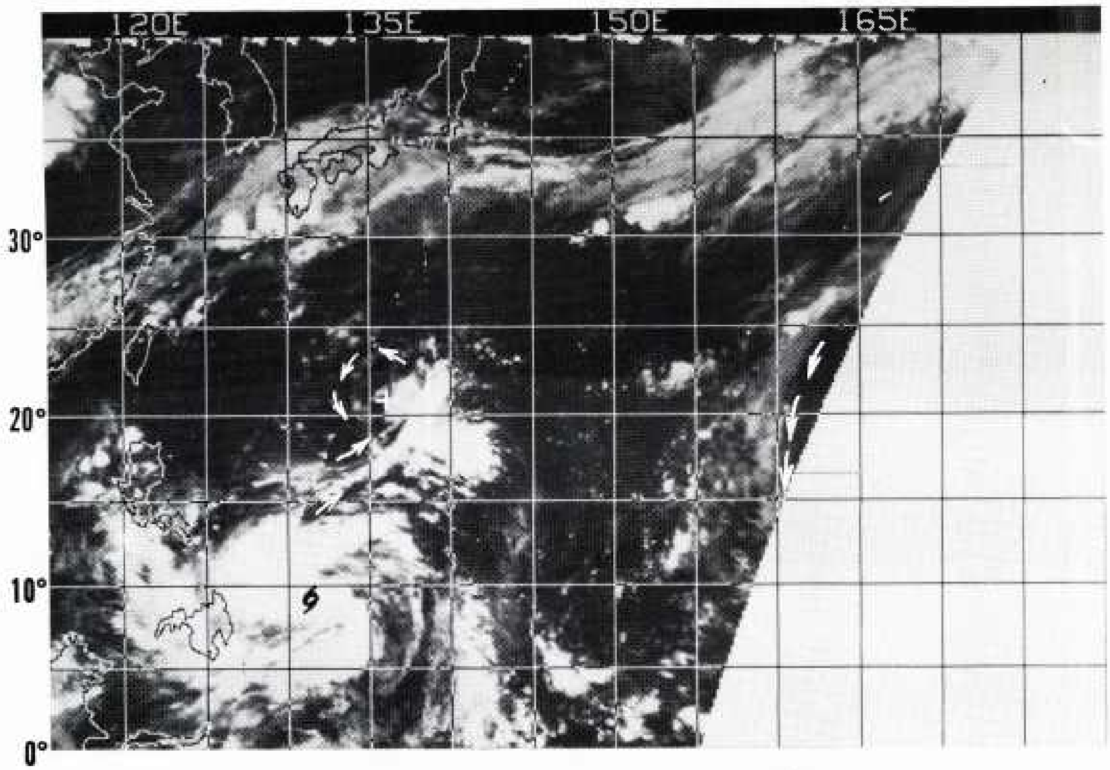

Figure 35. NOAA-1 IR mosaic near 1800 GMT on 23 June 1971.

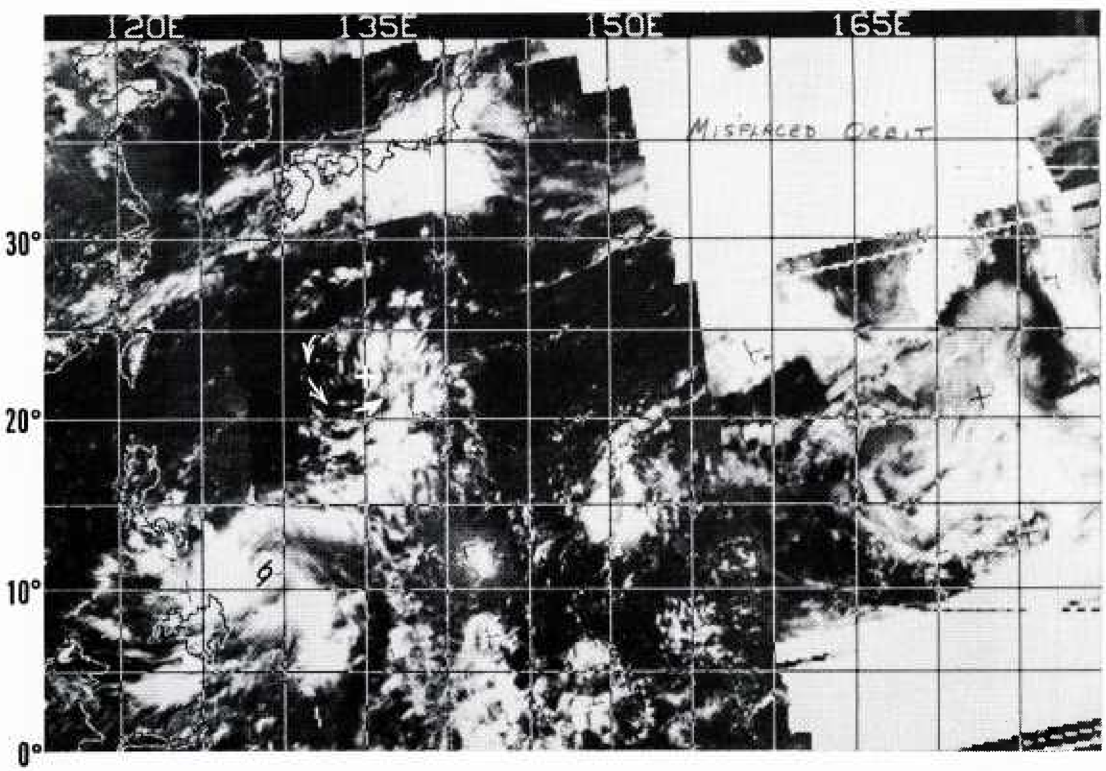

Figure 36. NOAA-1 AVCS mosaic near 0600 GMT on 24 June 1971.

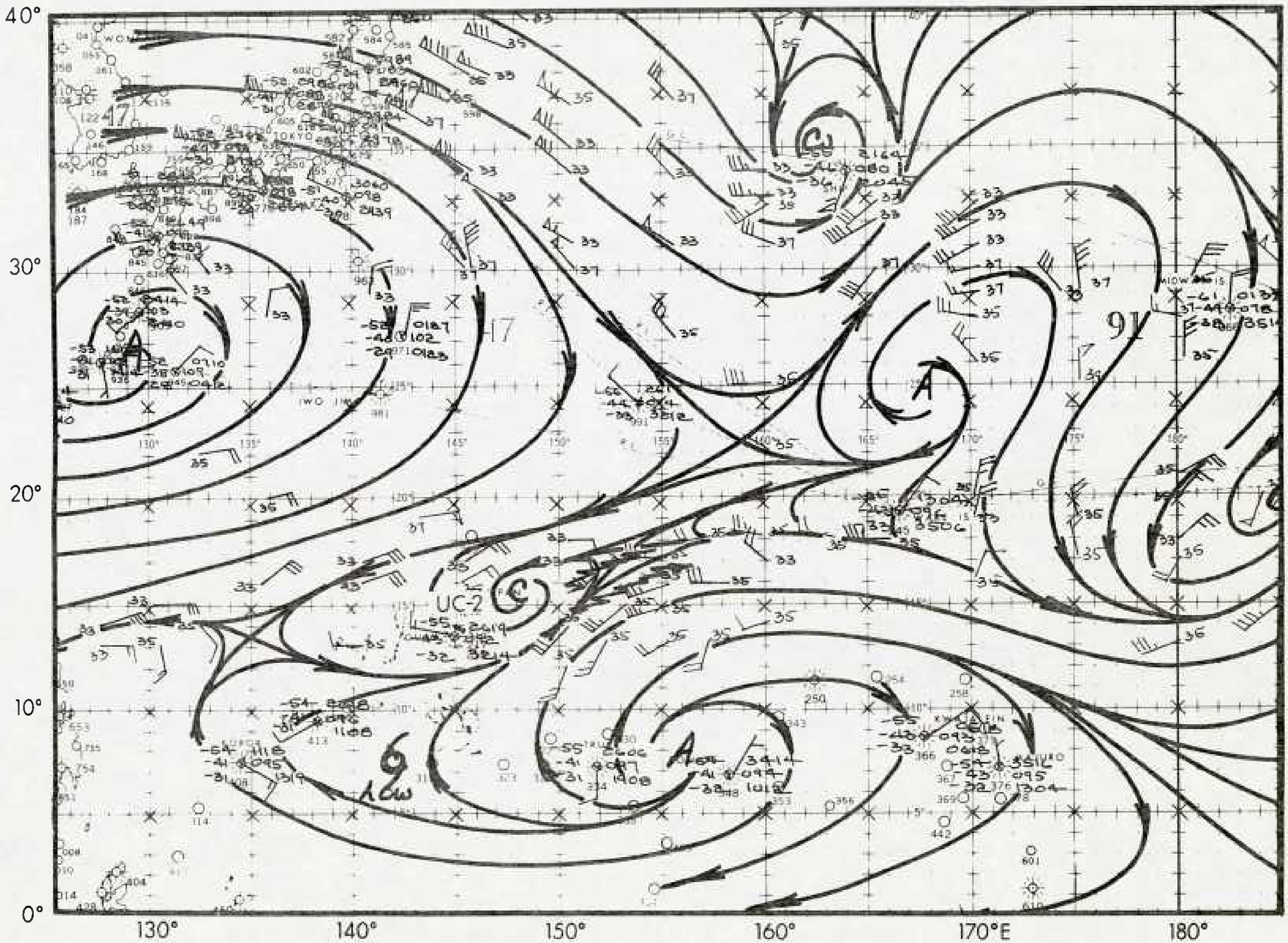

Figure 37. 250 mb analysis - 1200 GMT 28 June 1971.

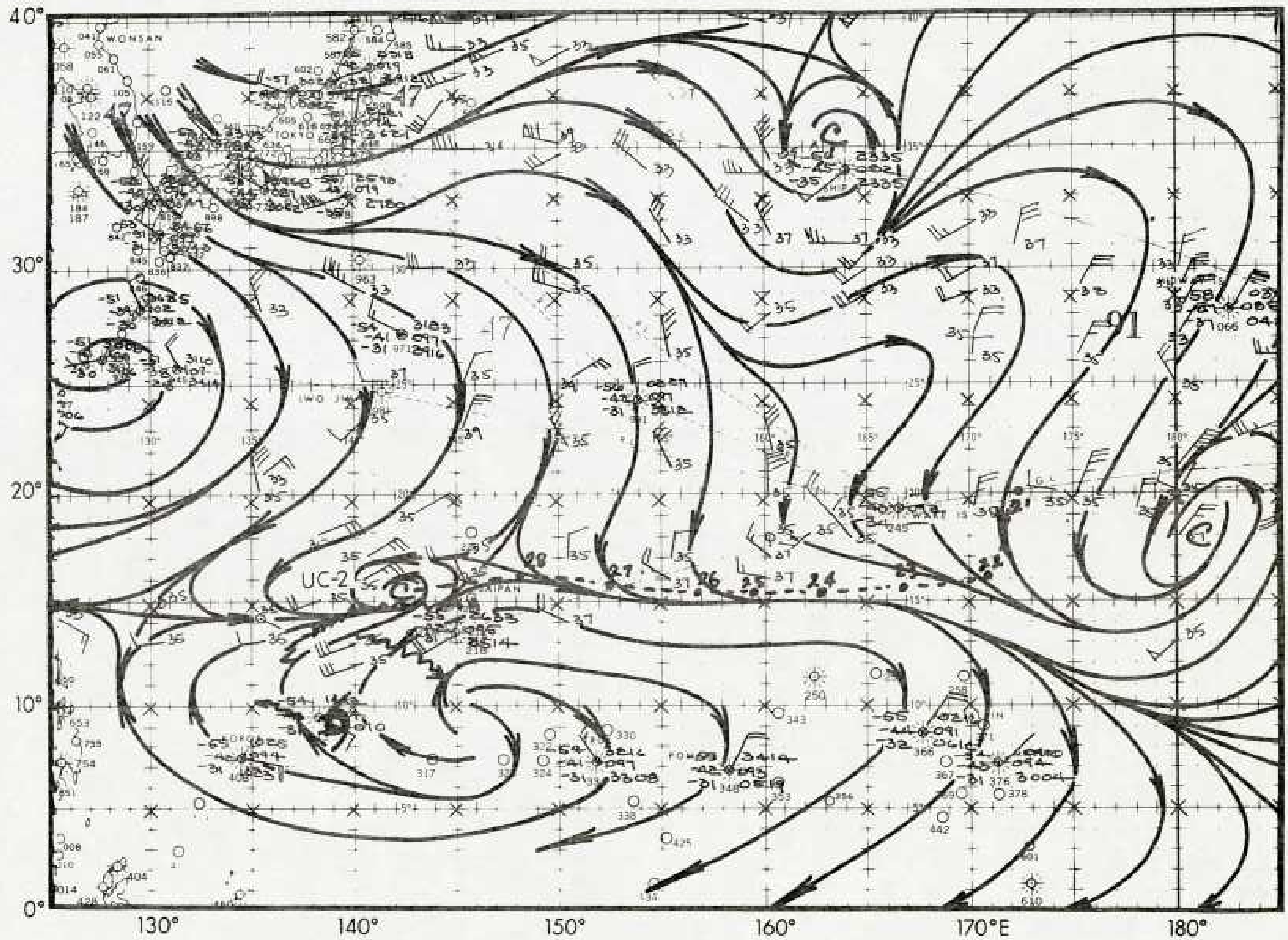

Figure 38. 250 mb analysis - 1200 GMT 29 June 1971.

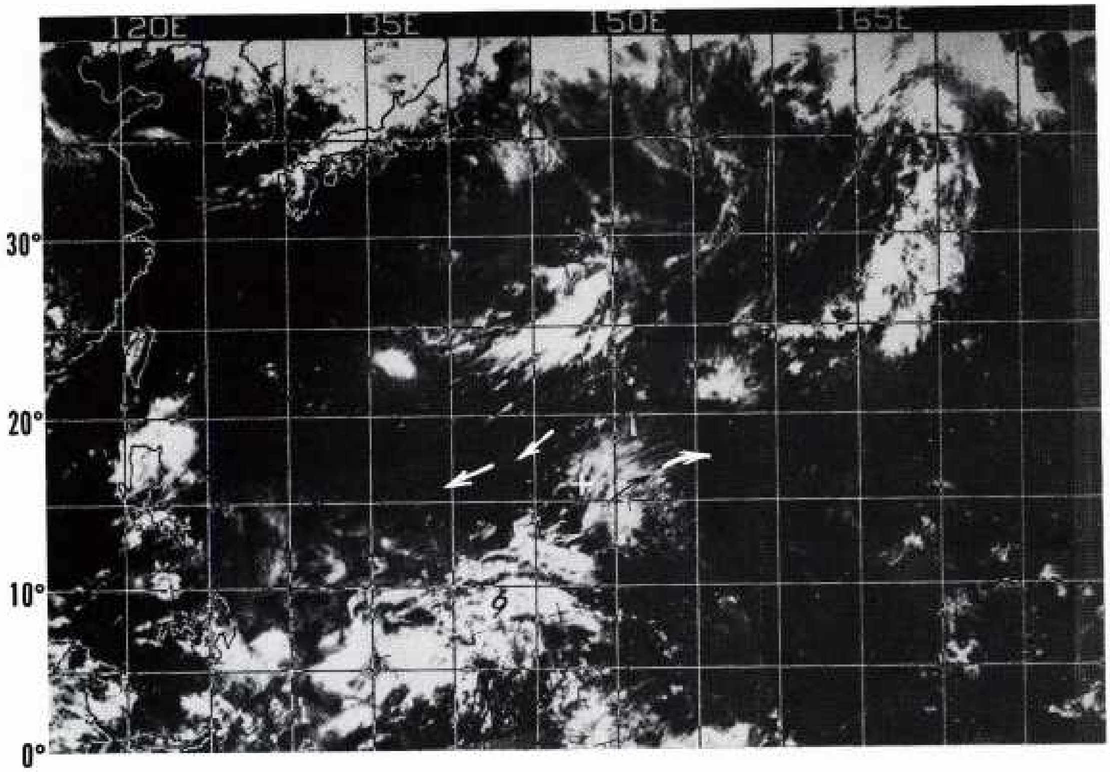

Figure 39. NOAA-1 AVCS mosaic near 0600 GMT on 28 June 1971.

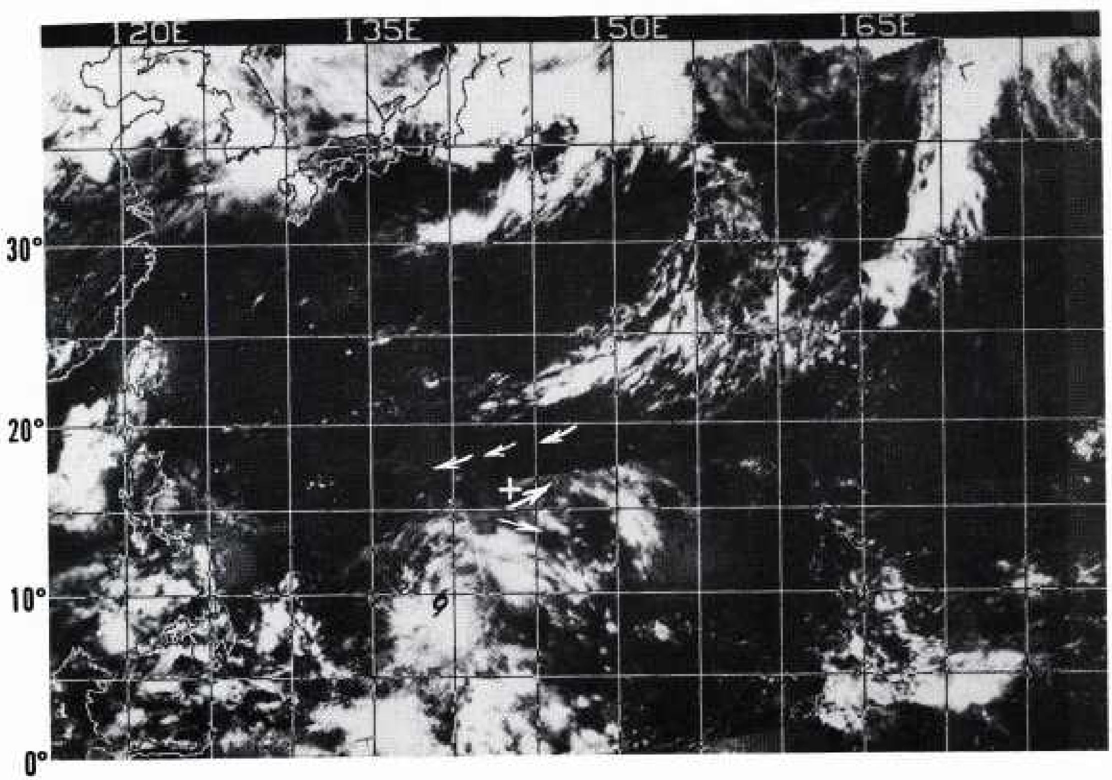

Figure 40. NOAA-1 AVCS mosaic near 0600 GMT on 29 June 1971.

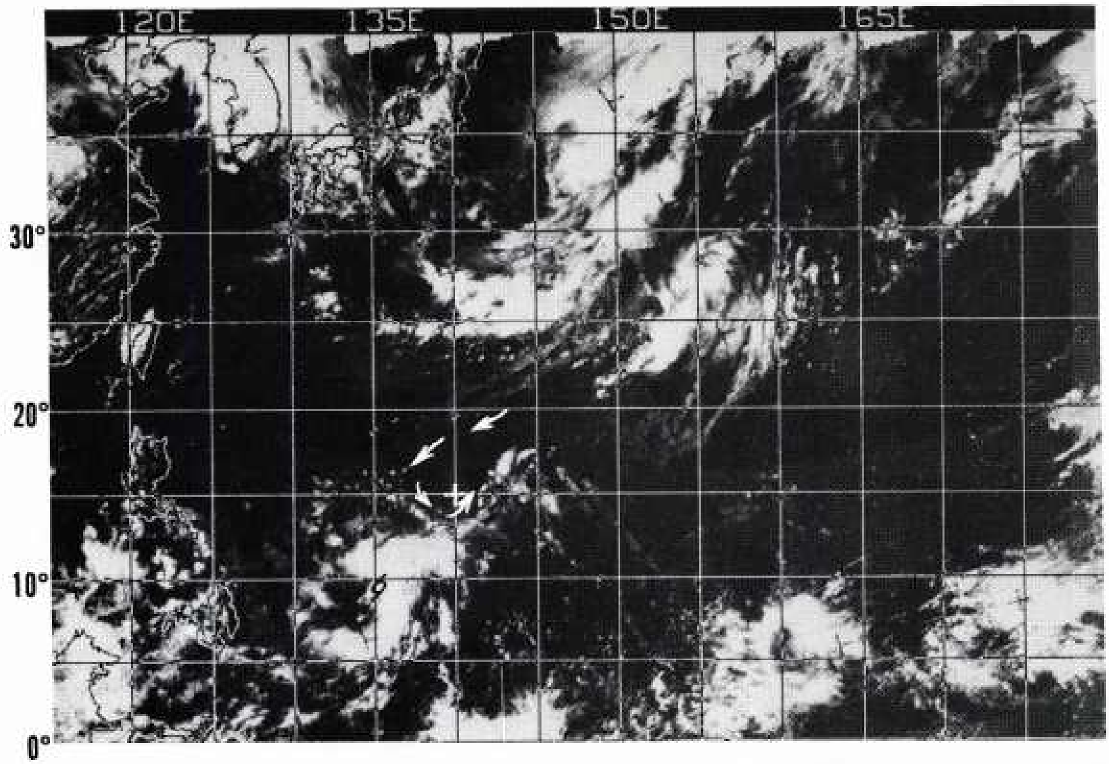

Figure 41. NOAA-1 AVCS mosaic near 0600 GMT on 30 June 1971.

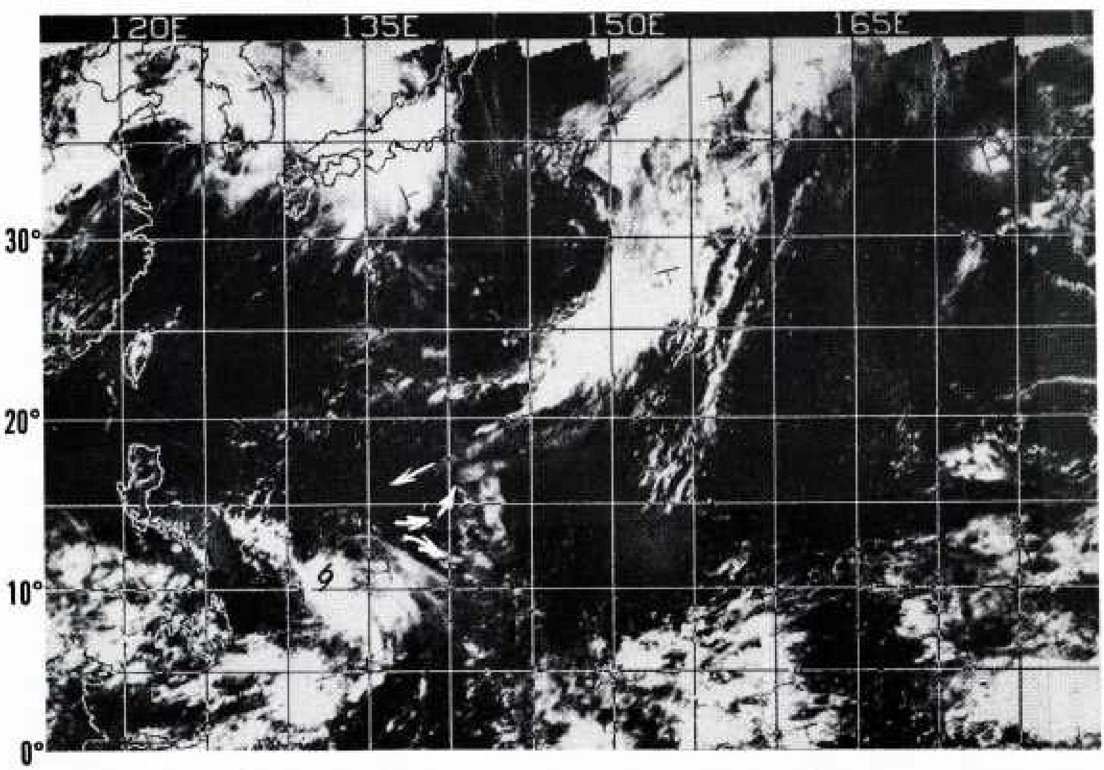

Figure 42. NOAA-1 AVCS mosaic near 0600 GMT on 1 July 1971.

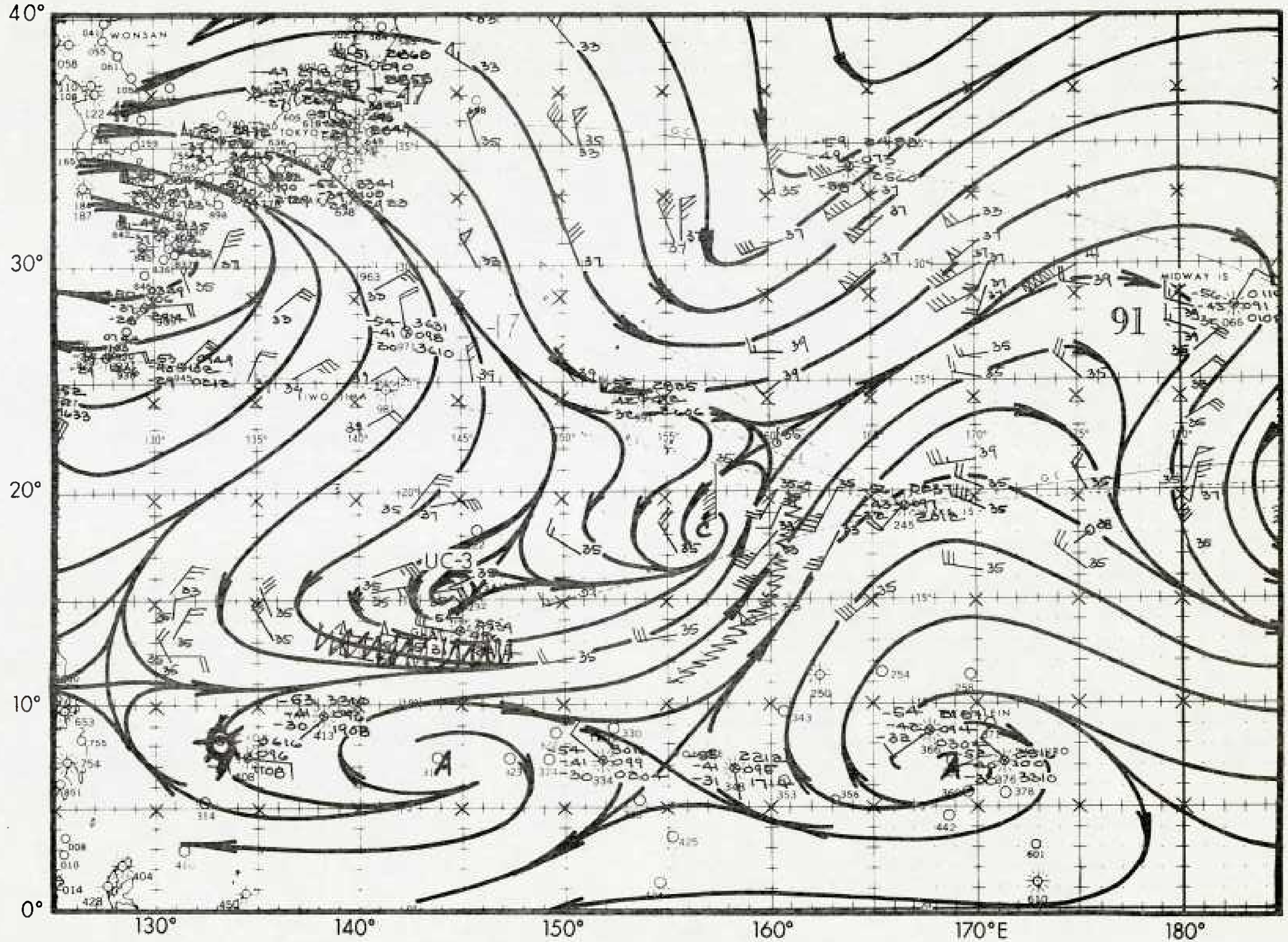

Figure 43. 250 mb analysis - 1200 GMT 11 June 1971.

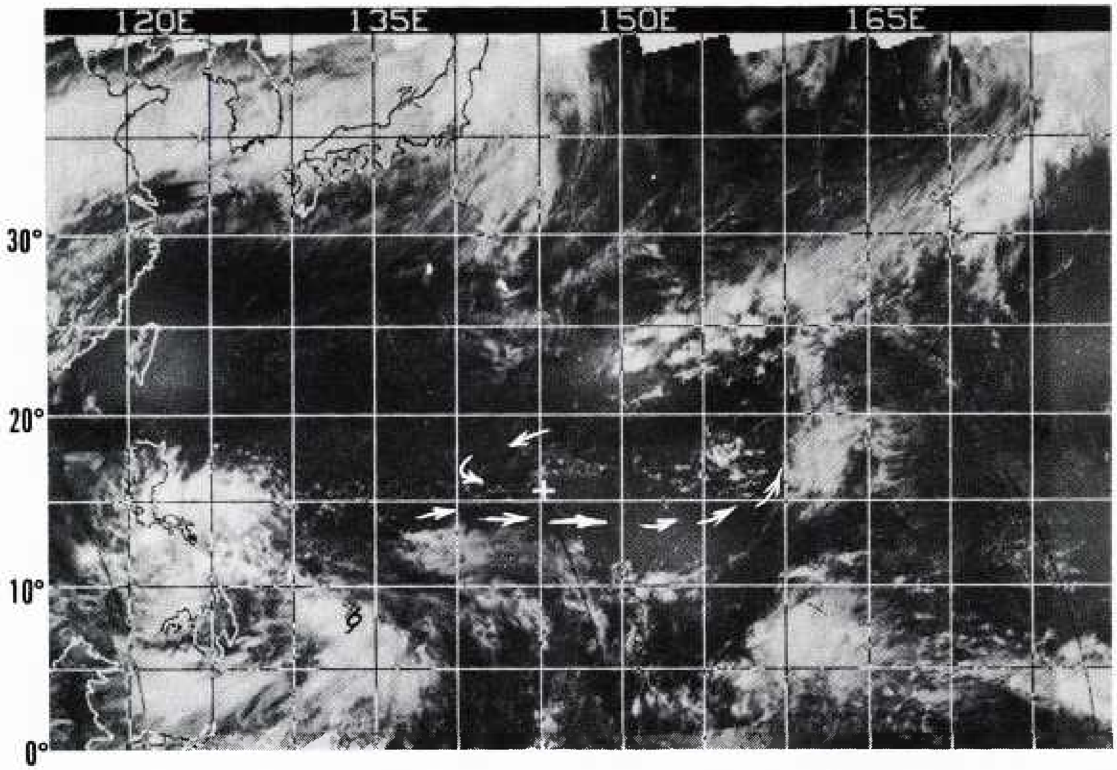

Figure 44. NOAA-1 AVCS mosaic near 0600 GMT on 11 June 1971.

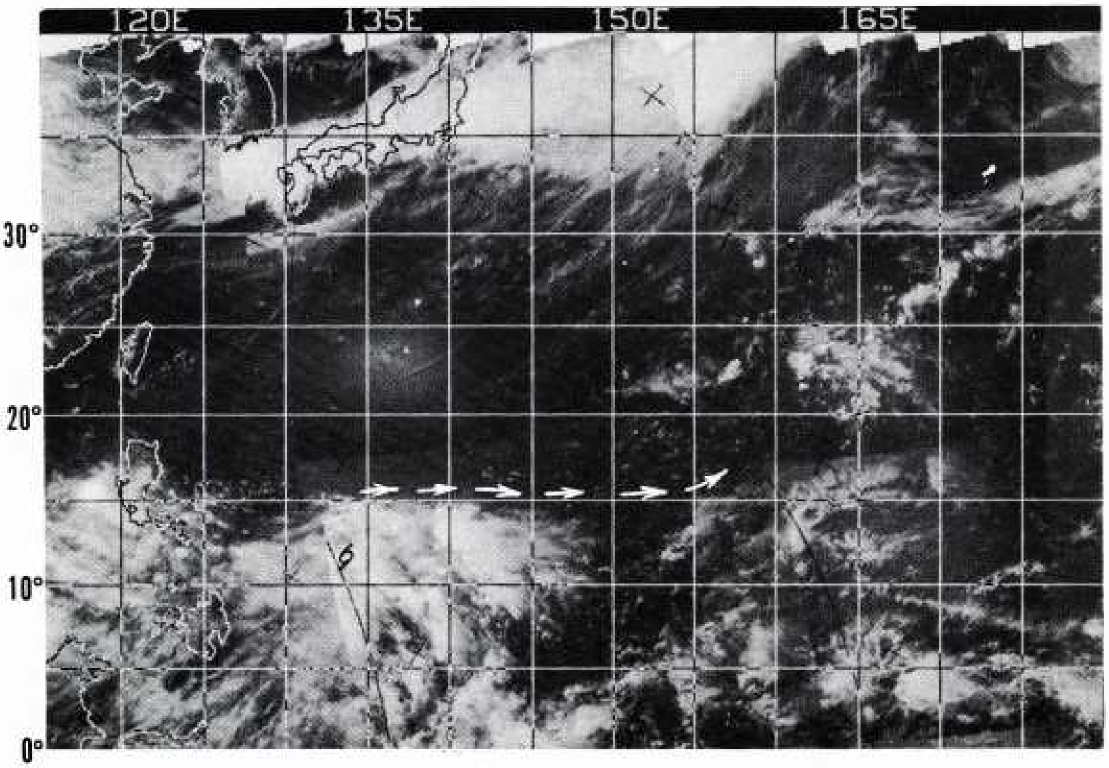

Figure 45. NOAA-1 AVCS mosaic near 0600 GMT on 12 June 1971.

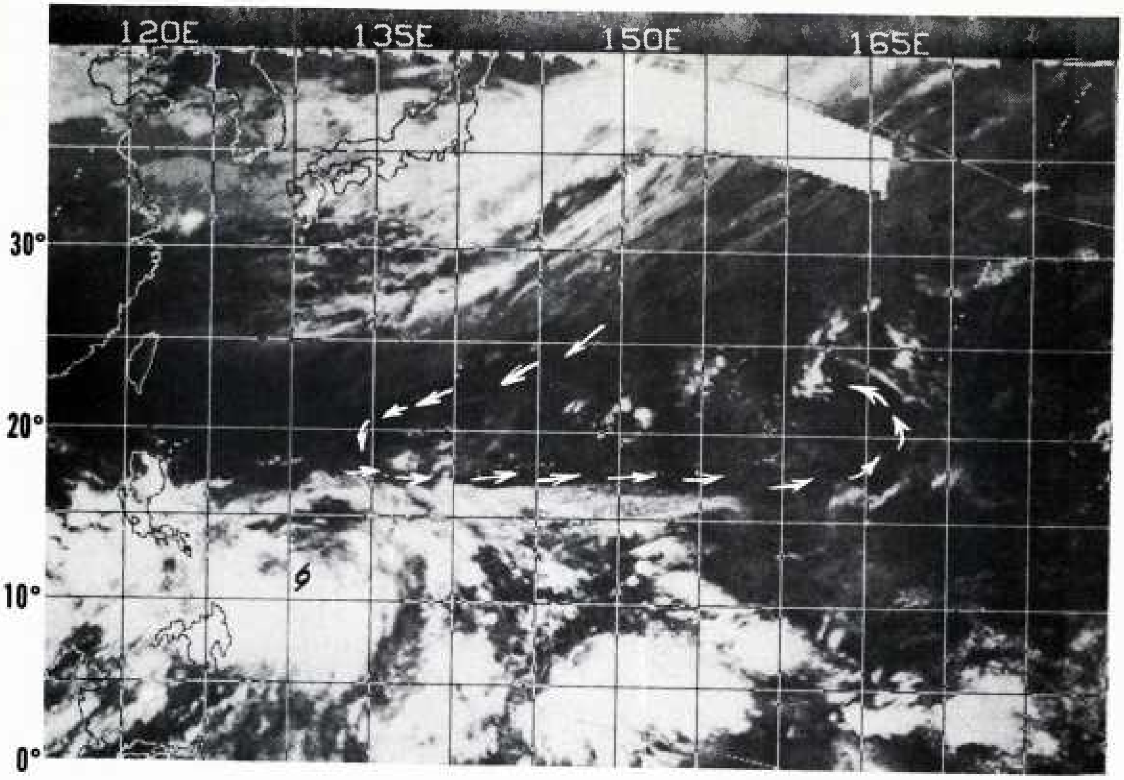

Figure 46. NOAA-1 IR mosaic near 1800 GMT on 12 June 1971.

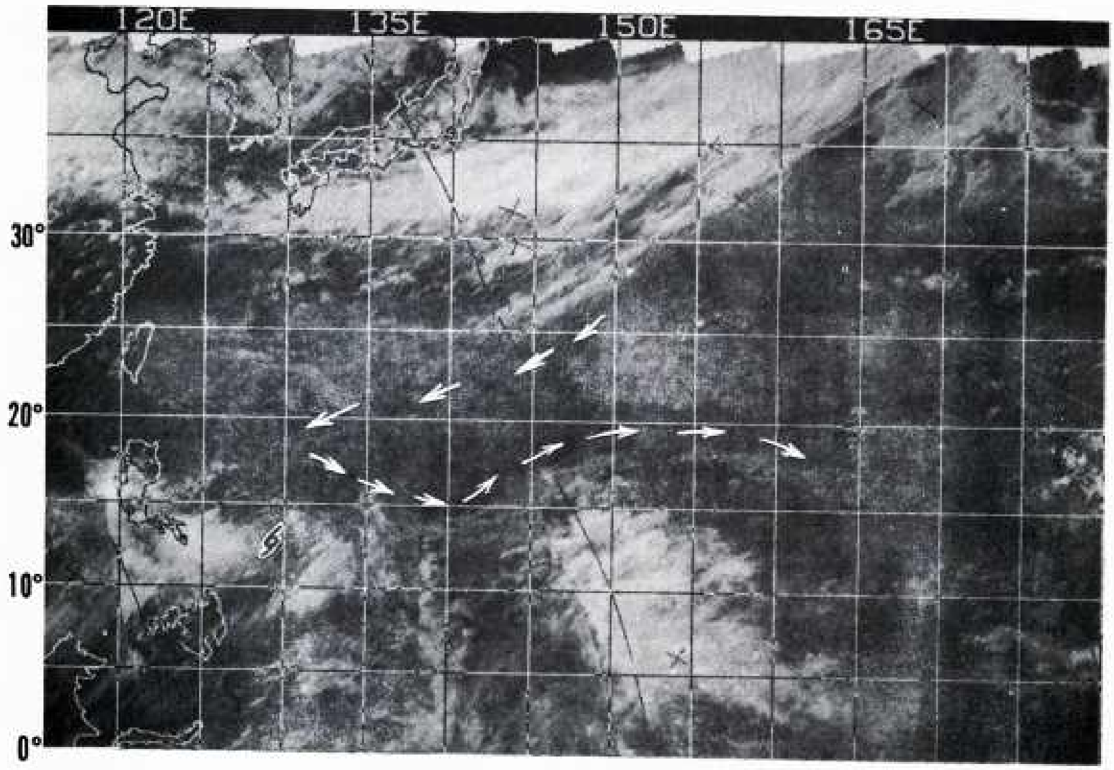

Figure 47. NOAA-1 AVCS mosaic near 0600 GMT on 13 June 1971.